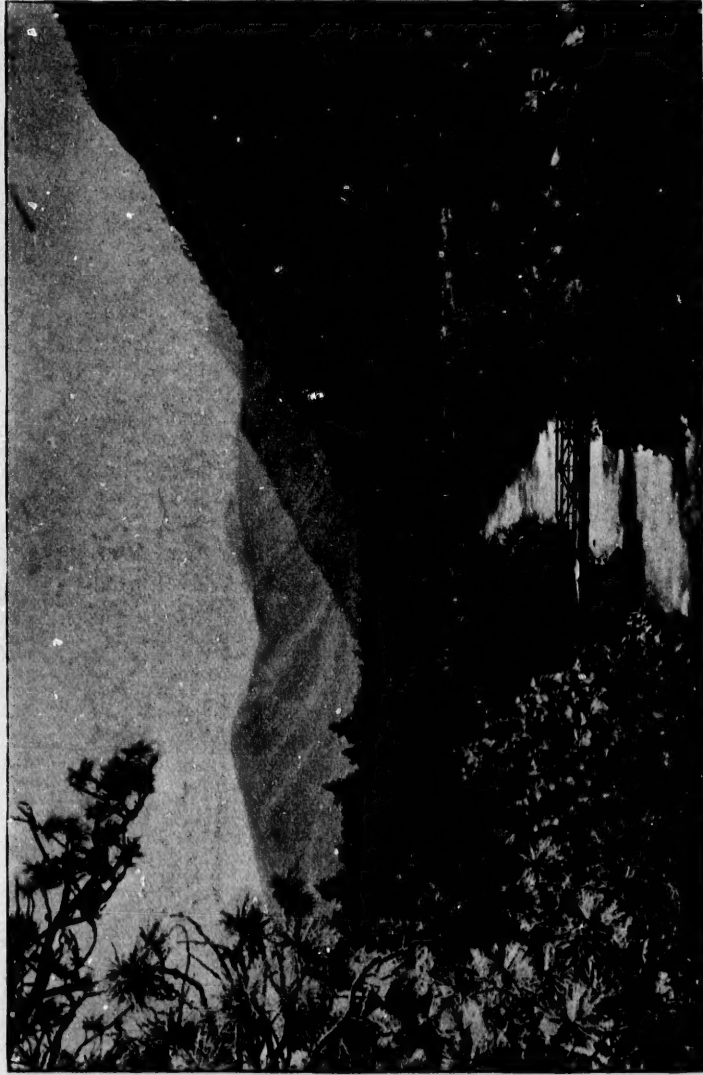




G. M. DAWSON.—Photo. July 22, 1890.
STEIN CREEK AND LOWER SPURS OF THE COAST RANGES.

GEOLOGICAL SURVEY OF CANADA
G. M. DAWSON, C.M.G., LL.D., F.R.S., DIRECTOR

REPORT

ON THE AREA OF THE

KAMLOOPS MAP-SHEET

BRITISH COLUMBIA

BY

GEORGE M. DAWSON



OTTAWA

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NOTE.—The bearings throughout the report are given with reference to the true meridian, unless otherwise specially noted. Average magnetic declination about 24° E.

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PHYSICAL GEOGRAPHY.

The Kamloops map-sheet, to which this report relates, covers a Area. portion of the Interior Plateau of British Columbia, with a comparatively small width of mountains of the adjacent Coast Ranges on its western edge. It is a square of which the sides measure eighty miles, and consequently includes an area of 6400 square miles, all parts of which are in the drainage basin of the Fraser River and its tributaries.

The province of British Columbia, extending from the 49th to the 60th parallel of north latitude, is practically co-extensive with about 900 miles in length of the Cordilleran belt, or Rocky Mountain region of North America. The two principal mountain systems of the Cordillera in British Columbia are the Rocky Mountains proper and the Coast Ranges.* These constitute its north-eastern and south-western borders respectively, if we exclude from consideration the insulated mountains of Vancouver Island and the Queen Charlotte Islands. Between these two limiting systems we find, on the side next to the Rocky Mountains, several less regular, though often equally lofty mountain ranges, which may be collectively referred to under the name

The Cordil-
leran belt.

*To avoid possible misconception, it must be explained that the Coast Ranges of British Columbia are orographically and geologically distinct from the Coast Ranges of California and Oregon. The name Cascade Range is on some maps extended to them from the mountains of Oregon and Washington to which it rightly applies, but this is wholly inappropriate, as the two mountain systems are entirely distinct, both in trend and in composition.

of the Gold Ranges, and between these and the inner margin of the Coast Ranges, lies the region described as the Interior Plateau.

Both these great bordering mountain systems of the Cordillera are comparatively modern, geologically speaking, while the Gold Ranges are, apparently, much more ancient. The Coast Ranges (with the adjacent mountains of Vancouver and the Queen Charlotte Islands) seem to have been first outlined about the close of the Triassic period and to have been re-elevated and increased in width toward the end of the Cretaceous period; while the Rocky Mountains proper are almost entirely due to movements of the earth's crust referable to the same closing epoch of the Cretaceous.*

The Interior Plateau.

The Interior Plateau of the southern part of British Columbia, may be described as having an average width of about one hundred miles, with a length, from south-east to north-west of about five hundred miles. Its mean height above the sea is probably about 3500 feet, but its elevation decreases gradually in a north-westerly direction, so that the southern part, with which we are more immediately concerned, considerably exceeds the height stated.

Its character and origin.

It is only when regarded in a broad general way and by contrast to the lofty and rugged mountains by which it is bordered, that this interior region can be designated a plateau. Seen from points along its larger and lower valleys, it might be described as a hilly or in places even a mountainous country. More carefully examined, it is found to consist, particularly in its southern part, of numerous blocks of plateau-like contour, separated by important depressions and differing considerably in their actual elevations. But there is every reason to believe that in the early part of the Tertiary period, the area of the Interior Plateau had become reduced by prolonged denudation to the condition of a nearly uniform plain. This condition must have resulted from a long continued period of stability, during which the height of the country relatively to the sea remained constant, enabling the streams to cut their beds down to what has been termed the "base-level of erosion," or to that minimum rate of descent, which, while it sufficed to unwater the district, did not practically admit of further reduction. After this had been attained, however, the reduction of elevations still upstanding between the main watercourses continued, till, in the end, these also approximated to the general level. Though never absolutely flat, the surface of the country thus became an approximate plain or what is known as a "peneplane."

*Report of Progress, Geological Survey of Canada, 1878-79, pp. 46 B, 48 B; Annual Report, Geological Survey of Canada, vol. II. (N.S.) p. 15 B; Trans. Royal Soc. Can., vol. III., sec. IV., pp. 6-7.

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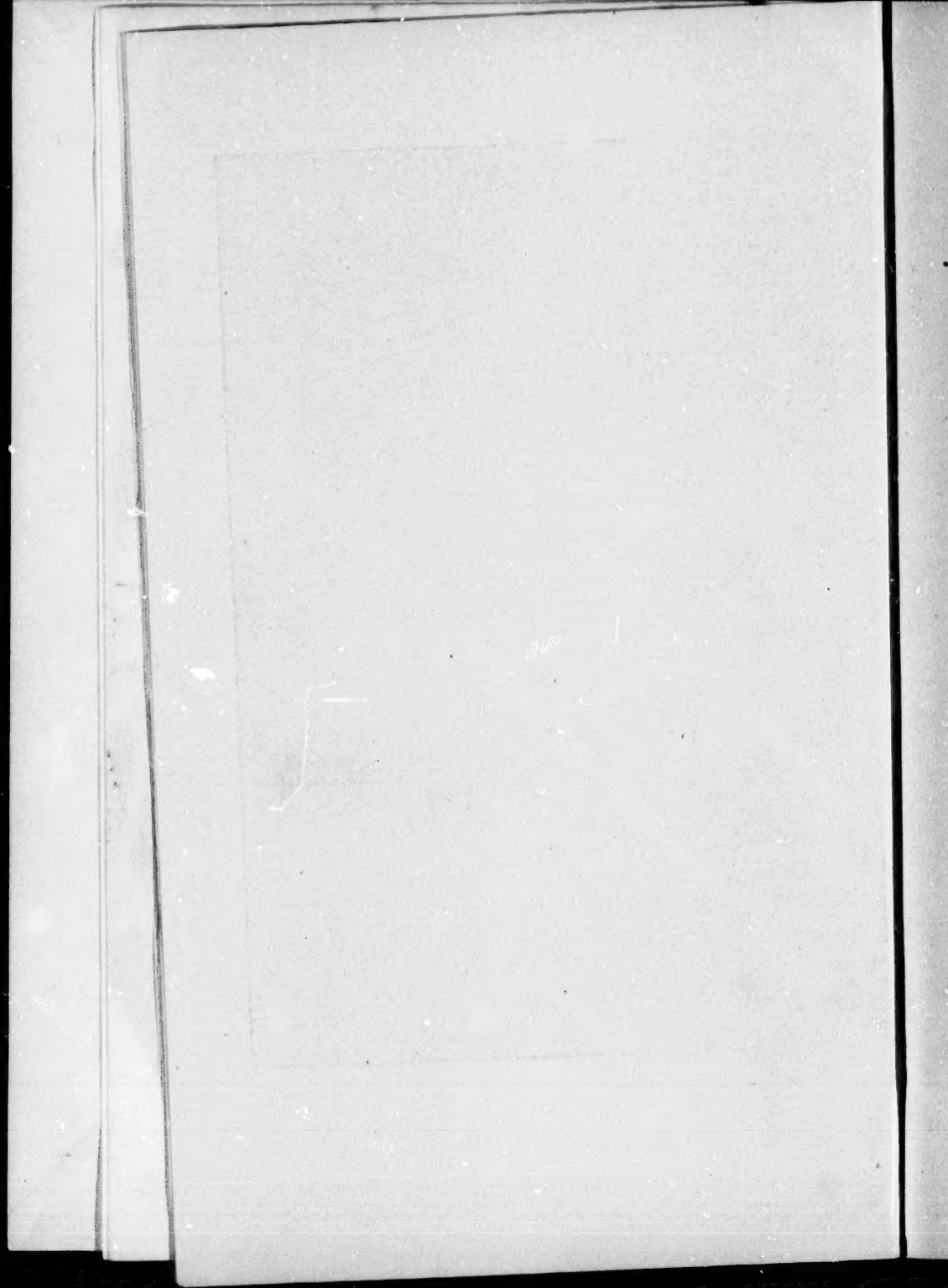
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G. M. DAWSON.—Photo. June 21, 1893.
LOOKING SOUTH-EASTWARD FROM CHOO-WHEELS MOUNTAIN.
Showing Forest-clad Plateau at elevations of 4,000 to 5,000 feet.



It appears further that the peneplane at this time formed has never since been entirely obliterated, although it has passed through several stages of elevation and depression and has even been subjected to more or less deformation due to earth movements. At certain periods, it has been an area of deposition of strata and the theatre of great volcanic eruptions, the results of which have been, in some places, to level up previously formed irregularities in the surface, in others, to produce local elevation. At intervening times, the natural forces of waste have been engaged in reducing these superadded irregularities toward the old plane, but during the latter part of the Pliocene Tertiary, with the country standing at an elevation higher relatively to the sea than at present, the greatest erosive changes tending toward the destruction of the ancient plateau occurred. At this time, the main rivers cut deeply into its surface, while their smaller tributaries were actively engaged upon the edges of the intervening blocks of plateau, degrading these, and, in some cases, producing considerable widths of lower hilly country along the larger river-valleys. Its history.

In the general description of the Tertiary geology of the region (p. 66 B) and in the subsequent discussion of the various periods of erosion in connection with the auriferous drifts further particulars of the evolution of the surface features at different stages are given. Additional details, with an extension of the same inquiry over the entire area of the province of British Columbia, may be found in a paper elsewhere published.*

Thus our idea of the Interior Plateau as an entity must include some reference to its origin and former condition. But even as it exists at the present time, it is not unnatural to designate this region generally as a plateau, for, standing upon any point of sufficient elevation, the great lower valleys are entirely lost to view, while the higher tracts run together everywhere in the distances to form a nearly level horizon line, above which the rugged forms of some of the adjacent mountains may stand out. It was indeed the recognition of this fact which led to the conclusion that the many existing isolated areas of plateau are but parts of an originally single feature, and which induced an investigation of its cause and age. Further, it may be added that the several existing plateau areas, though differing considerably in elevation, do not do so materially as between adjacent parts. They do not represent blocks of country which have been bodily uplifted or depressed by faulting, but parts of a gently inclined and undulating surface, so that in such a view as that above referred to, the differences in height are not at all apparent. Present appearance of the plateau.

*Trans. Royal Soc. Can., vol. VIII., sect. IV., p. 3.

Slope of the Plateau.

Within the area of the Kamloops sheet, near its middle line, the normal level of the plateau may perhaps be described as declining northward from about 4500 feet to about 3500 feet, and it is very possible that the early Miocene drainage of the country took place in that direction. On this particular line, however, it will be observed that the volcanic accumulations of the vicinity of Savona Mountain and of the Arrowstone Hills, superadded during the later Miocene, to some extent interfere with the regularity of the main old pre-Miocene plateau. Further to the east, the high Sil-who'i-a-kun Plateau forms another irregularity of the same kind.

Irregularities.

Toward the western edge of the map, it will be found (even in omitting from notice the deep but relatively modern valleys of the Fraser and Thompson) that the plateau does not regularly abut upon the Coast Ranges. Its regularity is here interfered with by several subordinate elevations, which are of two kinds—higher projecting ridges of the old rocks, and local volcanic accumulations of the Miocene period. The Marble Mountains and Pavilion Mountains are referable to the first category, the Clear Mountains to the second. But as the western edge of the plateau rises gradually toward the Coast Ranges, particularly in the south-western part of the area of the map, none of these stand out very boldly above it.

Different systems of valleys.

It will be understood from what has already been said, that the great valleys by which the Interior Plateau is now conspicuously trenched—those of the Fraser, the Thompson and their main tributaries—are relatively modern, being referable to the later part of the Pliocene Tertiary. This system of valleys is superposed upon an older one, believed to date from the earlier Pliocene, of which parts may still be traced meandering upon remaining blocks of the old plateau. Still older drainage systems, of which the streams took quite different courses, undoubtedly lie buried beneath the volcanic accumulations which are referred to the Miocene or middle Tertiary.

The bunch-grass country.

All the lower and larger valleys in the plateau region, up to an elevation of 3000 feet and sometimes considerably higher, are, in consequence of the dryness of their climate, either free from forest or dotted over with irregular groups of open wood or with single trees, of which *Pinus ponderosa* is the most characteristic. The terraces and slopes are naturally covered with bunch-grass (*Agropyrum tenerum*). This is the case in the valleys of the Fraser and Thompson, also in the valleys of the North and South Thompson to the limits of the map, and in those of the Bonaparte as far as the Chasm, the Nicola, Junction Valley, Hat Creek nearly to a point abreast of Cairn Mountain,



STUMP LAKE, FROM THE SOUTH
Showing open Grass Country of the Lower Valleys.

G. M. DAWSON.—Photo. Sept. 6, 1890.

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the lower part of Pavilion Creek, the valley of Loon Lake, Semlin Valley, the Deadman as far up as Gorge Creek, Copper Creek, Guichon Creek to the mouth of Meadow Creek, the lower part of Cherry Bluff Creek, Peterson Creek, Reservation Creek, the wide valley running south of Kamloops to Nicola Lake and the Upper Nicola River.

In these lower valleys, nearly all the land available for agriculture is Tillable land. situated, and in most of them irrigation is necessary to produce crops. The open bunch-grass slopes adjacent to these valleys are always most extensive along their northern sides, and in some cases country of this character extends far beyond the immediate valley into lower hilly tracts of the adjacent plateau. This is notably the case in the vicinity of Ashcroft, in the hilly tract on both sides of the North Thompson near Kamloops, in the vicinity of Stump Lake, on both sides of the Upper Nicola valley, and on the western slope of the Pavilion Mountains.

In the higher parts of all the main valleys above enumerated, and in those of very many of their tributaries, the country still continues to be open or but sparsely wooded, with an abundance of grass on the slopes or on the terraces and flats about the streams. Here, however, the bunch-grass is found only on the slopes most exposed to the sun, while various kinds of flat-leaved grasses, with wild peas, vetches and other species of herbaceous plants are more abundant elsewhere. A change of the same kind is indeed found to occur with increasing elevation in all parts of the country, so that, in climbing from almost any one of the lower valleys, the nearly treeless slopes are exchanged at a certain elevation for open woods, consisting of Douglas fir (*Pseudotsuga Douglasii*) or yellow pine (*Pinus ponderosa*). The width of this belt varies much with the exposure, and depends, also largely upon the steepness of the slopes itself, but in the aggregate the area thus characterized is very considerable. Conditions of the same kind obtain over some of the lower parts of the plateaux themselves. This is especially the case on the Green Timber plateau, where open grassy country is interspersed with areas of forest, in this case largely composed of small black or bull pine (*P. Murrayana*), and in which innumerable small lakes, some of them saline, occur. The Bonaparte plateau, with open woods, somewhat resembles the last, while similar, though less considerable, areas of the same kind are found about Toon-kwa Lake to the south of Lavona, near Uren's on the Upper Deadman River and along Meadow Creek. Many smaller patches of a like character might be enumerated.

The various classes of country above described constitute the chief Pastoral grazing grounds of the region, upon which large herds of cattle and lands.

horses are maintained. The lower tracts are naturally the best winter ranges, and these it is now becoming customary to fence, in order to reserve them for winter feeding; while in many of the higher valleys, abounding in natural meadows, hay is now annually cut and stacked in the summer, in order to provide a reserve against the occurrence of an exceptionally severe winter.

The forest
country.

Much the larger part of the plateau area is, however, covered with dense forests of trees of medium or small size, including, in order of abundance or nearly so, black pine (*P. Murrayana*), white spruce (*Picea Engelmanni*), Douglas fir (*Pseudotsuga Douglasii*) and balsam spruce (*Abies subalpina*). In such tracts, narrow irregular borders only along the banks of streams or swamps, produce any grass; few trails or practicable routes for horses are found, marshy spots are frequent and great regions of almost impassable "windfall" occur. For the last-mentioned impediment to travel, the recurrent fires are responsible. These in consequence of carelessness on the part of both whites and Indians have devastated great tracts. In some places where such fires have passed more than once, the woods have been locally almost completely removed, but the soil, being by the action of the fire itself much deteriorated, even then produced as a rule but a scanty growth of grass of indifferent quality. In other instances, an almost impenetrably dense crop of young trees springs up immediately. In the course of years, these dense forests of northern type will undoubtedly for the most part disappear, and although this will facilitate travel, and render the examination of all parts of the region much easier than it is now, it appears certain that no great concurrent advantage will result in regard to the extension of grazing grounds, while the supplies of the streams which now yield water for purposes of irrigation will be seriously impaired.

Alpine park
land.

At or about an elevation of 5000 feet, the dense character of the woodland country above described begins to change. The forest, which is composed chiefly of black pine, white and balsam spruce, with (in the south-western part of the region) the white-barked pine, begins to open out. Without any marked decrease in the size of individual trees the forest covering becomes more sparse, and as somewhat greater heights are reached, the trees arrange themselves in separate clumps with grassy intervals. In many places park-like country of this kind is somewhat extensive. This is particularly the case between 5000 and 6000 feet on the Nicola Plateau and Lytton Mountains, in the Clear Mountain range and on the Sil-who'-a-kun Plateau. The Marble Mountains and higher parts of the Pavilion Mountains, are so bare of soil that such conditions are not

reproduced upon them, and the same is generally true of the Coast Ranges. In the Sil-who'i-a-kun region, as the name itself denotes, this high open country was, within the memory of Indians still living, a home of the caribou—an animal now found no nearer than the uplands and mountains in the vicinity of the Clearwater branch of the North Thompson. The aggregate area of such alpine park land is not inconsiderable, and during a few months of summer it is always singularly attractive, watered by innumerable rills, and covered with gay alpine flowers. During that season, it is capable of affording nutritious pasturage to cattle, and although it has not yet been utilized for this purpose, there can be no doubt but that it will be so employed in the near future.

The upper limit of the growth of any trees in an arboreal form, may be stated for the region as being about 7000 feet, and, at this height, the more hardy forms, last enumerated, survive only in the sheltered valleys. In regard to the upper limit of thick forest, it is pretty clear that this is defined by the amount of the snowfall. Above a certain height, varying somewhat with locality and exposure, the depth of the winter snow is so considerable that, if the forest became dense, the snow would not disappear from beneath its shade soon enough to enable any appreciable growth to occur. Thus any tendency to a thick growth is naturally checked, for only a certain number of trees, or clumps of trees, to a given area find the necessary conditions for permanent existence. A different cause must, however, be found for the sparsely wooded condition of the lower valleys, and this it appears is the absence of sufficient moisture. A limited number of trees, with their widely extended roots, practically absorb all the moisture which the soil is capable of yielding, and, so long as they exist, prevent the establishment of any new arboreal growth.

Causes of
sparsely
wooded tracts

On referring to any general map of British Columbia, it will be seen that the Kamloops sheet includes but a narrow selva of the inland side of the Coast Ranges, or wide belt of mountainous country which runs parallel to the coast for the entire length of the province. This selva consists in fact of but one of the component minor ranges of this complex of mountains, bounded to the east by the Fraser Valley and to the west by a somewhat important parallel depression which has not been explored, but which appears to be occupied by the headwaters of the Salmon River and Quoiasek River. The axis of this range is granitic, while both its flanks consist largely of altered stratified rocks, often schistose or slaty but not true or crystalline schists. Except in the greater importance of these stratified rocks here, this part of the Coast Range is, however, so far as known, identical in

Part of the
Coast Ranges
included in
the map.

its character and structure with the whole extent of the mountainous country in this vicinity and may thus be taken as typical of it.

From the valley of the Fraser, no adequate idea of the topography of the Coast Ranges can be formed, as the lower shoulders of the mountains preclude any general view of their higher parts. A fine view of one part of the range may be had from the line of the railway, between Lytton and Nicoamen, in ascending the Thompson valley; but in order to obtain a just conception of its character, it must be seen from points along the east side of the Fraser of more than 5000 feet in height, or from some of its own summits.

Eastern front
of the range.

The side of the range bordering the Fraser, is found to present a nearly uniform wall of mountain slopes to the river, and is composed of very steeply inclined high spurs of nearly similar form, each of which is separated from the next by a deep narrow gash, which may either be that of a small torrent or that of one of the main streams rising far back in the range. Above and behind these spurs, the mountains become more rugged in shape and show more bare rock, while here and there an apparently dominant peak stands notably above the rest and carries large patches of snow throughout the summer.

Its higher
summits.

Such a view of the range may be gained from almost any of the mountains on the east side of the Fraser, but on ascending one of the peaks of the range itself to an elevation of 8000 feet or more, it is found that the points which seemed to dominate, as viewed from lower levels and from the eastward, owe this appearance chiefly to their proximity to the edge of the range. From such a peak, it will be observed that there is little regularity in the trend of the component mountain masses of the range, but that there is a very notable uniformity in the elevation of its higher points. It will be observed that a large number of these approximate in height to 8000 feet, while a few only, reach or slightly surpass 9000 feet; that there are few instances of really dominant summits with lesser subsidiary mountains grouped around them, but that in widely extended views to the south, west, or north, the very numerous and closely set sharp summits run together to form a jagged, but in the main nearly level horizon line. To illustrate this point, it may be mentioned that, on one occasion, from Stein Mountain, looking over the crests of all the nearer mountains, the summit of Mount Baker, of the Cascade Range, more than a hundred miles distant, was clearly recognized as a markedly outstanding point, although its elevation is not much more than 10,000 feet.

Extent of
snow.

In looking southward over these mountains after midsummer, about half the surface of their upper parts is still covered with snow, the

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remainder showing bare gray, or rusty, and somewhat brownish rock. Some of the higher and more sheltered valleys remain deeply filled with snow throughout the year, and there are occasional small masses of glacier-ice upon a few of the heights at a considerable distance back from the Fraser valley.

Although thus, in such a general view, almost monotonous from their similarity in height and from the repetition of wave like and pyramidal forms, the mountains are extremely rugged and diversified in detail, with cliffs and crags of varied and picturesque forms and sharp irregular crests running up from the subordinate ridges to the main summits. Amongst these, and in the higher parts of the valleys, the mountain goat (*Aplocerus montanus*) finds a secure retreat, in which it is very seldom disturbed by the hunter.

Local
diversity.

It will be noted on the map that the main streams draining these mountains rise far back to the westward, and that they show a tendency to flow in a direction nearly transverse to that of the range. In their lower parts, the valleys of these streams are usually mere cañons, or wild gorges, with exceedingly steep and high bordering slopes. A higher series of tributary valleys, though still deep, are wider in proportion to the size of the streams, with somewhat lighter slopes, often wooded, though occasionally interrupted by rock slides or by cliffs. About the heads of the valleys of this class, and in the case also of their many smaller tributaries, alpine valleys with an abundant fresh herbaceous growth and scattered clumps of lichenized trees occur, and these generally terminate, either in cirque-like amphitheatres surrounded by cliffs, rock-slides and steep slopes of snow, or in narrow V-shaped gorges. A higher series of cirques is also observed in some places, in which the surface is divided between rocks and snow, with here and there a small tarn or pool, and scarcely a trace of vegetation of any kind, but gray, solitary and alpine in their aspect.

Character of
valleys.

Reverting to what has been said of the great general uniformity in height of the majority of the culminating points and ridges of the Coast Ranges, the question naturally presents itself in what manner such uniformity has been brought about. It can have little if any connection with the original form and height of the elevated tract of the earth's crust out of which the existing ranges have been carved by a prolonged process of denudation; nor is it peculiar to the mountains here particularly considered, for a similar condition has been noted elsewhere in many mountainous regions. Cases may occur in which the surface of a peneplane like that previously alluded to, or that of a plain of marine denudation, has, subsequent to the time of its formation, been thrust up to such heights as to admit of

Cause of
general uni-
formity in
height.

Region of
maximum de-
nudation.

the production of mountain ranges in the course of its degradation, but such cases must be rare.

The suggestion is made that such uniformity in the higher points may depend fundamentally upon the greatly accelerated rate of denudation above a given plane of height in a mountain region. This plane would appear to be that limiting the existence of perennial snow, and below which the slopes are more or less continuously forest clad. It is well known that the continual presence of water during the summer, with the occurrence of frost almost every night, constitute peculiarly effective conditions of denudation. It has then only to be assumed that the progress of denudation in the partially snow covered regions is several or many times greater than below it, to account for the rapid disappearance of rock-masses above this height.

The general reduction of outstanding points in an entire region to the level at which maximum denudation ceases, must of course imply a considerable period of stability at a certain height and under given conditions; but it is precisely in those mountain regions which are not the newest geologically, that such effects are most marked. In the Coast Ranges of British Columbia, the great quantities of broken rock everywhere surrounding the actually highest summits shows the activity of the forces here adduced; for all such material, in addition to that carried away by the streams, must have accumulated since the close of the glacial period. The explanation here offered is a general one, but as it occurred to the writer in connection with the study of that part of the Coast Ranges included in the Kamloops sheet, it may appropriately be alluded to in connection with these mountains.

Facts bearing upon other points of the physical geography of the Kamloops sheet, such as the lakes, and the changes referable to action during the glacial period, are accorded mention in subsequent pages of this report.

Climate.

The climate of the region included in the Kamloops sheet is largely dependent on its orographic features. Both the annual and the diurnal range of temperature is great, while the precipitation is scanty. Even in that part of the Coast Ranges included in the area, the snowfall, though considerable, is in no way comparable to that which occurs in the western parts of the same mountainous belt. It is, in fact, as a result of this barrier between the Pacific and the Interior Plateau that the prevalent westerly* and moisture-bearing winds become desiccated before they reach the latter region.

*An examination of the stunted remnants of trees on the flat summit of Zakwanski Mountain, 6600 feet, indicated the prevalent direction of winds at that elevation to be from S. 75° W.

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The climate of Kamloops itself, situated near the centre of the Interior Plateau region, at a height of 1150 feet, and thus illustrating that of one of the lower valleys, is represented in the following table, kindly furnished by the Director of the Meteorological Service. The amount of rainfall is unfortunately not included, but this is probably somewhat greater than at Spence's Bridge, where it is about ten inches in the year.

Data for
Kamloops

THE annual average of the mean highest, mean lowest, highest, lowest and mean temperature, mean daily and monthly ranges and per cent of clouded sky, derived from observation, 1877 to 1893, inclusive, at Kamloops, B.C.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Mean highest.....	29.2	29.6	50.0	60.2	68.2	77.2	83.7	84.2	74.0	57.3	42.9	34.4	.....
Mean lowest.....	14.6	11.4	27.9	36.7	45.5	49.7	55.2	54.9	46.1	39.4	30.9	23.0	.....
Highest.....	48.1	46.5	62.4	73.7	79.1	83.9	87.3	84.0	85.7	72.9	60.9	48.7	97.03
Lowest.....	8.7	10.3	9.6	28.0	33.1	39.0	48.7	48.7	55.2	24.7	10.5	0.9	10.03
Monthly mean.....	21.0	20.5	38.9	48.4	56.7	63.5	69.1	69.0	60.4	47.1	36.3	28.9	46.69
Mean daily range.....	14.6	18.2	22.1	23.5	22.9	27.5	28.5	29.3	27.9	17.0	12.0	11.4	21.03
Monthly range.....	56.8	56.8	52.8	45.7	46.0	53.4	48.6	45.3	50.5	48.2	50.4	47.8	.....
Clouded sky, p. c.....	74.0	68.0	58.0	63.0	76.0	67.0	46.0	.....	57.0	69.0	78.0	.....	.....

It is unnecessary to repeat the description of the causes and results of the flow of relatively warm and moist currents of air over such a barrier as that of the Coast Ranges, and their subsequent descent to a lower country, which have been given in my former reports on other parts of British Columbia.*

Chinook
effect.

It is sufficient to state that the effect is that variously known as the *foehn* or *Chinook*, now well understood and described in text-books of meteorology. The air, already dried in its passage over the range, is mechanically warmed in proportion to the amount of its descent, and is thus rendered still more susceptible of absorbing moisture and incapable of affording any rainfall. This effect is naturally most intense in the immediate lee of the mountain range, as is very clearly seen in this particular district. Standing upon some high point, as for instance, one of the summits of the Clear Mountains, the Coast Ranges may not infrequently be seen to be buried in clouds, which as they detach themselves and drift eastward are gradually absorbed, a clear sky obtaining over the western part of the plateau. New bodies

* Report of Progress, Geol. Surv. Can., 1879-80, pp. 76 B-78 B; Annual Report, Geol. Surv. Can., vol. III. (N.S.) p. 22 B.

of cloud, from which local showers fall, may often at the same time form about the higher parts of the plateau itself.

Distribution
of rainfall.

A study of these conditions, with the aid of the contour-lines on the map, will show how it happens that the lower valleys and those nearest to the Coast Ranges are the most arid parts of the district, while the humidity of many of the higher parts of the plateau, particularly those situated to the eastward, is at the same time still considerable, enabling them to be the sources of perennial streams which may be employed in the irrigation of the lower and drier tracts.

Trees as an
index of cli-
mate.

A complete meteorological survey of the region would undoubtedly supply numerically accurate proof of these conditions, but in the absence of such data, much may be gathered from an examination of the natural vegetation, and more particularly of that of the native trees. A number of observations on the heights attained by various plants will be found tabulated in one of the appendices to this report. It is of course impossible to say how far the limiting range in height is determined by temperature, and how far by humidity, the effect being in each case a resultant principally of these two causes; but in respect to the other resultant known generally as "climate," and particularly in regard to the bearing of climate on agriculture, the indications thus afforded are important.

Altitudes
reached by
several trees.

The Douglas fir (*Pseudotsuga Douglasii*), and the yellow pine (*Pinus ponderosa*), because of the facility with which they are recognized and observed, may be regarded as ready indexes of this kind, and an examination of the heights at which these trees were last seen in various parts of the region, will show that the upper limit of the first-named tree declines from the vicinity of the Clear Mountains to the eastward—a distance of some fifty miles—from about 5500 feet to 4500 feet, while the yellow pine similarly declines from about 5000 to about 3500 feet in the same distance. It may further be noted, that the white-barked pine (*Pinus albicaulis*) is practically confined in its range to the dry alpine country characteristic of the Nicoamen Plateau and the Clear Mountain Range, immediately to the east of the Coast Ranges, where, between levels of 5500 and 6000 feet, it is one of the most abundant and characteristic trees. The actual elevation observed in each particular place is largely governed by the subsidiary effect of the exposure or direction of the slope of the country, but this also has an equally marked effect on agricultural possibilities.

Peculiar cli-
matic condi-
tions.

Many local climatic effects, which are of considerable importance and interest in the districts in which they occur, are naturally found in a country with boldly marked physical features like this. Thus, in the upper part of the Botanie Valley, a place resorted to every year by



G. M. DAWSON.—Photo. Aug. 27, 1890.

NEAR PORCUPINE RIDGE. [5,900 feet.]
Showing high Alpine Plateau with Engelmann's Spruce.

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the Indians at the season for digging edible roots, the vegetation is not only notably luxuriant, but unusually varied. The cedar (*Thuja occidentalis*), white pine (*Pinus monticola*) and devil's club (*Fatsia horrida*), all plants seldom met with in this region and rather characteristic of a damp climate, are found here; while at the same time there is a large extent of open slopes, and no such continuous thick forests as might be expected with the conditions for the growth of these plants. It appears however, that as the result of causes not very well understood, the winter snowfall is here unusually great. The Indians say that it lies on the ground to the depth of three feet and that in particular winters it is much deeper.

Owing to similar local conditions, a strong up-river wind develops almost every afternoon in summer in the lower part of the Fraser Valley, while during the winter season a frigid down-river wind frequently prevails. Similar land and sea breezes blow through all the main valleys in the Coast Ranges,* but there is some evidence to show that these affect only the lower strata of the atmosphere. Thus, on one occasion, while upon the summit of Botanie Mountain (8620 feet) the afternoon was characterized by a light westerly air, while in the Fraser Valley at Lytton and even in the Botanie Valley immediately below, a violent southerly wind was blowing. Local winds.

The upper limit of agriculture in the region depends principally upon the elevation at which killing night frosts occur during the summer months, or season of growth of the crops. Practical experience has shown that, in so far as wheat is concerned, this limit seldom exceeds 3000 feet above the sea-level, while it is often found to be at considerably lower levels in consequence of local circumstances. Barley and other more hardy crops may of course be grown at somewhat greater altitudes, but as a rule the surface of the plateau generally is much too high for agricultural occupation. The highest areas upon which wheat is successfully grown occur near the wagon-road on the southern and western slopes of Pavilion Mountains and on the upper part of Hat Creek, the elevation being in the first case from 3500 to 4000 feet and in the second about 3500 feet. The highest farm upon the part of the Pavilion Mountains named, is situated a little above 4100 feet and here, though barley and oats may be grown successfully, wheat and potatoes are not profitable crops. It will be observed that all these places occupy sheltered positions near to the inner margin of the Coast Ranges, where, as already stated, the *föhn* effect is most notable. Limit of
agriculture.

* Annual Report, Geol. Surv. Can., vol. III. (N.S.), p. 22 B.

Crops of the
lower valleys.

In the lower valleys, such as those of the Fraser and Thompson, notwithstanding the occasional severity of the cold of winter, the summer heat is very great and nocturnal frosts are not known at this season. The extent of arable land in these valleys is not very considerable, but, with a proper supply of irrigation-water, many of the benches and slopes may be rendered exceedingly productive. Grapes, water-melons, musk-melons and tomatoes grow luxuriantly, and may be cultivated as field crops; fruit trees of all kinds flourish, and considerable quantities of beans for the local market are produced by Indian and Chinese cultivators. Where southward-facing slopes occur upon which water can be brought, it is certain that by terracing the surface, extensive vineyards might be established; and as it is a well known fact that the better qualities of light wines are produced near the northern limits of the vine, it appears possible that a not unimportant future may await the intelligent development of some parts of these valleys for this purpose.

Minimum
temperatures
at various
heights.

As a general rule, it is found that the temperature of the atmosphere decreases in ascending to the amount of about one degree Fahrenheit in 300 feet. This, of course, applies to the mean temperature, while the lowest nocturnal temperature during the season of growth is the important one in limiting agriculture in this region. As throwing some light upon this question, the minimum readings, extracted from the meteorological observations kept during the progress of the explorations, have been tabulated in accordance with the elevations at which they were taken, for comparison with those registered simultaneously at the Kamloops meteorological station. The resulting tables appear as an appendix to this report.

Larger
animals.

A note may be added respecting some of the larger animals of the region. As already stated, the caribou (*Rangifer Caribou*), once an inhabitant of the high plateau between the head-waters of the Deadman and Tranquille and the North Thompson still known to the Indians as Sil-who'i-a-kun, is now locally extinct. The wapiti (*Cervus Canadensis*) was also not long ago abundant within the area of the Kamloops sheet, and weathered antlers of this animal may still be found, particularly in the hills near Stump Lake. Its resorts being in the open or lightly wooded tracts of the lower country, it was soon and easily exterminated by hunters. The black-tailed deer (*Cariacus macrotis*) is still abundant in the district, and the white-tailed deer (*Cariacus Virginianus*) is occasionally seen. Work done by beavers is frequently met with in all parts of the region, but the animal itself is now rare. The black bear (*Ursus Americanus*) is not uncommon, and the grizzly (*Ursus horribilis*) also occurs, particularly in the vicinity

of the Niccoamen Plateau. The mountain goat (*Aplocerus montanus*) is rather abundant in the higher parts of the Coast Ranges, and the big-horn, or Rocky Mountain sheep (*Ovis montana*), may often be seen in the mountains near Bridge River. Wolves (*Canis lupus*) are met with occasionally, and coyotes (*Canis latrans*) are in most years abundant below the main limit of the forest country. The rattlesnake inhabits only the lower and dry valleys, the greatest height at which it has been observed being 2520 feet, at Tso-tin Lake in the Pass Valley.

The natives inhabiting the entire region covered by the map, belong to the Shuswap stock, and speak a single language with dialectic variations. Such particulars as I have been able to ascertain concerning them have been made the subject of a separate paper.*

THE MAP AND METHODS OF SURVEY.

When the Geological Survey of Canada first extended its work to British Columbia in 1871, the geology of that province was practically unknown. In that year, lines of reconnaissance were carried through a part of the interior of the province by Dr. Selwyn and the late Mr. James Richardson. In succeeding years, up to and including 1875, Mr. Richardson's time was chiefly devoted to the examination of the Cretaceous coal-measures of the coast. In 1875, Dr. Selwyn again traversed the province on his way to the Peace River region, and the writer began his exploration of the interior region of British Columbia, which has been continued, though with some intermission, to the present time. Mr. A. Bowman is also to be credited with his map and report on the Cariboo mining district, published in 1889, and Mr. R. G. McConnell with his section across the Rocky Mountain ranges published in 1889, which has afforded valuable data for the eastern part of the province.

Previous geological observations.

With the partial exception of the two last-named surveys, and some of those by Mr. Richardson in the Nanaimo and Comox coal fields, the work so far published has been almost entirely of the nature of reconnaissance, often extending over very large districts. This method of survey was rendered necessary by the demands for information on the structure of the country, and its prospective value in different parts, connected with the examination and discussion of various alternative railway routes, previous to the definite location of the Canadian Pacific railway on its present line.

Reconnaissance work.

*Trans. Royal Soc. Can., vol. IX., ser. II.

The map presented herewith, is therefore practically the first result of an attempt at a moderately detailed investigation and delineation of the geological features of any considerable area in British Columbia, and it is intended that further sheets of the same size and on the same general plan shall eventually be completed to cover possibly a large part of the province.

Earlier maps
of the present
district.

In 1877, the writer spent the entire season in the investigation, along its more early travelled lines of the southern part of the interior of the province, and a preliminary report and map were published in the volume for 1877-78. This map covered an area of about twenty-five thousand square miles. As the settlement of the country progressed, and after the railway had been completed, it became desirable to provide a more detailed and exact map, and Mr. A. Bowman consequently spent some time in adding to the topographical and geographical data for the same area. In 1887, a limited edition of a topographical map, including the later work, was printed, and in the following year the writer returned to the district with the purpose of revising and completing the geological data. The entire district was traversed in this year along a number of routes, special attention being given to the search for and examination of any sections which appeared to be likely to yield facts bearing on its general structure.

Adoption of
4-mile scale.

The result of this season's work was, however, to show that the scale of the map (eight miles to the inch) was too small to enable the geological intricacies of the region to be properly represented, and thus, in 1889 and 1890, the work was chiefly confined to the north-western quarter of the old map, of which the scale was doubled, making a map of the same size as the first, but covering only one-fourth of the original area. The increased scale, however, rendered necessary a complete redelineation of the geographical and topographical features, which part of the work has been skilfully carried out by Mr. J. McEvoy.

Want of geo-
graphical
data.

Had a sufficiently accurate geographical outline been available for use in mapping the geological structure, much time would have been saved, and a better result would undoubtedly have been obtained. As it was, the line of railway, with some lines surveyed by the Dominion Lands Branch near it, were practically all those which could be depended upon. Elsewhere the geographical and geological work went on concurrently, and the interrelation of the geological facts was seldom clearly seen, till it became possible to lay these down on the geographical and topographical basis subsequently compiled in the office.

In order to complete, in any reasonable time, the map of a rugged mountainous country some 6400 square miles in area, with the means actually at disposal, it was necessary to strive after no greater accuracy than that sufficient for the scale in view. Thus, starting from the line of railway and the few other surveyed lines mentioned as fixed stations, a loose network of triangles was carried out between the natural points; a sufficient number of the more prominent elevations and peaks being ascended in turn and occupied as transit stations for that purpose by Mr. McEvoy. Where paced surveys had been made by Mr. Richardson in 1871, and by the writer in 1877, these were employed to fill in detail, but the greater part of the detailed topography depends upon track-surveys by Mr. McEvoy.

Mode in which
this has been
supplied.

At each of the transit stations, and at many intermediate points, complete or partial profile sketches of the hills and mountains were made, upon which the vertical and horizontal angles were marked. Upon these, in conjunction with barometric observations, the heights given and the approximate contour-lines of the map depend. The barometric heights have generally been obtained by means of two or three good aneroids, checked by station readings regularly made at Kamloops; all the aneroids being directly compared from time to time with a mercurial barometer, and the readings being corrected by a scale of errors thus drawn up. The latitude of as many as possible of the transit stations was directly ascertained by sextant observations, within limits of error of a few seconds, and many intermediate points were also fixed in the same way.

As already noted, the geographical and geological work was carried out simultaneously. In fact, the writer, with his assistant, Mr. McEvoy, usually travelled together, the field party consisting besides of but three or four men, generally Indians or half-breeds, provided with a few pack-horses and riding animals. When high points were occupied as transit stations, these were at the same time employed to study, as far as possible from a distance, the distribution of the rock series. The geological observations were noted at the time on the topographical sketches, and subsequently checked on lines of traverse made in the surrounding country. Distant views of the kind referred to, were found to be particularly useful in affording information respecting the outlines of the basaltic plateaux, which would otherwise have cost much time and labour to define adequately.

Method of
field work.

From what has already been said of the general topography of the country, it will be understood that, as a whole, it is not an easy one to examine. While the larger valleys and lower tracts are generally open

Difficulties en-
countered.

grass country, or are but lightly wooded, the higher plateaux and rough hills are frequently densely covered with forest, or encumbered with alien trees in such a manner as to render them almost impassable. Other considerable tracts are characterized by high rugged mountains, the elevations met with within the sheet ranging from about 400 feet above sea-level to over 9000.

Routes

The district is crossed by the main line of the Canadian Pacific railway, and is traversed besides by several roads and by a number of "trails" or travelled tracks; but large intervening blocks of country, which are seldom or never visited save by Indian hunters, have had to be explored for possible routes with considerable expenditure of time and labour; and although the length of route examined in the course of a day was seldom more than fifteen miles, and frequently much less because of physical obstacles met with, it was not often that the same camp was occupied or returned to on two consecutive nights.

It may be added, that the crushed and greatly weathered character of most of the rocks, together with the fact that in the Interior Plateau region they are often completely disguised by a crust of lichens, in most cases renders the recognition of rocks at any distance or from mere inspection almost impossible. The exposure must be actually reached and attacked with the hammer before its nature can be ascertained, and this is often a matter of difficulty, and one involving time and labour.

Degree of accuracy of the map.

It has been considered necessary to outline the methods of survey, as above, in order to indicate the degree of accuracy which may be supposed to attach to the results. Nearly all the routes followed, whether travelled trails or mere exploratory lines, are indicated on the map, this being the best way of showing where the geological features have actually been examined on the ground. A certain average standard of accuracy has been aimed at, and although at every point additional detail and more minute examination present themselves as desirable, each step in this direction increases many fold the time and labour necessary to the completion of a map. As it now stands, the map is offered as the best possible under the circumstances and on the scale adopted. It is believed that it will be of practical utility as an aid to the development of the mineral wealth of the district, and it is hoped that it may also be found to be a substantial contribution to the general geology of the exceedingly complex western part of the Cordillera of North America.

Geological isolation of British Columbia.

In regard to the systematic geology of British Columbia generally, it must be understood that our knowledge of this, so far as it goes, has been developed by slow degrees within the limits of the province itself,

beginning almost from first principles. This has been necessarily the case because of the absence of established general sections of the formations met with in any part of the length of the western portion of the Cordilleran belt. The early explorations of the geological pioneers in California, together with those of Prof. Whitney and his assistants, were scarcely of a sufficiently definite character to afford a basis of reference for any rocks below those of the Cretaceous system, while the systematic and detailed work done by the Fortieth Parallel Survey was almost entirely confined to the territories east of the Sierra Nevada—a region not structurally comparable with that to the west of this range, or with that which forms the greater part of the area of British Columbia. Within the past few years, however, and to some extent concurrently with the observations here reported on, geological work of a definite character has been undertaken in California by the United States Geological Survey, the results of which, in so far as they have been made known, tend to show a close relationship as to composition and structure between the rock-series there, and that of which the main features had already been developed in British Columbia. Reference is made in the sequel to such analogies and points of difference as have so far been brought to light in the course of this later work in California.

With special reference to the Kamloops map-sheet, it may be added, ^{The Kamloops map.} that while the earlier and more extended examinations previously made of this and other parts of the province enabled its investigation to be begun with a general knowledge of the sequence and character of the formations, the more detailed section now presented has been practically worked out within the area of the sheet or in its immediate vicinity. Thus, while this section may be accepted as a type in the further progress of the geological mapping of neighbouring regions, no one is more conscious than the writer of its essentially provisional character in some respects.

ARRANGEMENT OF GEOLOGICAL MATTER.

In the following pages, under the heading of *General Geology*, an outline of the main features relating to the several formations met with in the area of the Kamloops sheet is given, the evidence upon which each has been referred to its position in the geological scale is set out, and the relations of the several formations with others known in the western part of the continent is discussed. In this part of the report the formations are treated of successively, beginning with the Cambrian, which is the oldest recognized in the district. ^{Divisions of the report.}

relation to the
ap.

The next division of the report is occupied by what may be termed *Descriptive Geology*, being a more detailed treatment and examination of the various principal sections afforded by the region, with local notes and facts relating to the geographical distribution and composition of the various rock-series. This necessarily occupies some considerable space. If it were possible to present a map drawn to a large scale, resulting from surveys and examinations so complete that the details of the composition and character of the rocks could be adequately represented upon it, much of the descriptive portion of the report might be omitted. In the actual circumstances this must, however, be relied upon to supplement the map. In other words, the descriptive matter required stands very nearly in inverse proportion to the completeness of the map which it is intended to accompany.

Classification
of the older
rocks.

With the knowledge now gained of the region included by the Kamloops sheet, it is generally easy to distinguish the Tertiary, Cretaceous and Plutonic rocks from each other and to separate these from the remaining rocks of the region. Where points of doubt are still found in these separations, they are chiefly due to imperfect exposures or to the incomplete examination of certain parts of the district. When, however, all these have been coloured in upon the map, the remaining mass of older rocks presents much greater difficulties. They may, in fact, be described as forming a 'complex,' of which the unravelling has so far proceeded but to a limited extent. The results of the work carried out on them appear to show that Cambrian, Carboniferous and Triassic strata are present, but they do not exclude the possibility of the existence of other formations which should intervene in the normal geological scale between these. It has been endeavoured, so far as our information concerning these basal rocks of the district allows, to separate them under the heads above named; but this separation is not yet so satisfactory as to admit of a strictly chronological treatment in every part of the region. Thus, in the pages which deal with the descriptive geology of these older rocks, the arrangement adopted is, almost necessarily, in part based on the districts in which they occur, though the developments believed to represent the Palaeozoic rocks are in the main described first, while those rocks classed as a whole in the Triassic system are taken up subsequently.

Order partly
geographical.

The typical development of the Cache Creek formation is first noticed, as being that which is best understood, while its less definitely known representatives, with other associated rocks, are next referred to. The rocks which have been excluded from it as Cambrian, in the north-east part of the sheet, are then described. Finally, the great mass of

strata which is referred to the Nicola (Triassic) formation is discussed, but with these it is found convenient to treat also of some rocks attributed to the C  che Creek formation, because of their regional proximity and the fact that they form parts of general sections, which it appears to be best to notice in each case as a whole.

Both of the above mentioned sections of the Report relate, however, to what may be termed the 'solid geology' of the region only. A separate chapter is devoted exclusively to the 'surface geology,' or the examination and description of the superficial deposits or 'drift'; the character and distribution of which are largely due to action during the glacial epoch, assumed to mark the close of the Tertiary period proper. No recapitulation of this part of the report is included under the head of General Geology, and it may be regarded as constituting a separate essay, subsidiary to the first two divisions, although the facts disclosed by it are scarcely less important, particularly in their reference to the character and distribution of the gold-bearing gravels of the region.

In each of the three foregoing divisions of the Report, the bearing of the ascertained facts on economic questions relating to mineral deposits and mining is constantly alluded to; but in order to facilitate easy reference to all the economically important facts, so far as they are known, a fourth division of the Report is devoted to the summary treatment and enumeration of these, and to the details respecting various metalliferous districts which may prove to be of immediate importance to the prospector and miner.

THE TABLE OF FORMATIONS.

As a key to the geological structure of the region, the subjoined synoptical table of the formations met with is given. From this all details have been eliminated, leaving only the main facts presented in the most concise form. In explanation of the table it may first be stated that it relates to what has been termed the 'solid geology' alone. The known unconformities or breaks in the series are indicated by the horizontal lines, but it must be understood that the value of these is very unequal, some representing long, while others represent comparatively short time-intervals, to an extent not fully ascertained. It will further be observed that in some cases local names have been adopted for the groups or formations. This has been done where it appeared to be necessary for the purpose of description, and particularly in cases where the precise limits, above or below, of a geological series are not known. The introduction of such new names

Arrangement
of the Table.

has, however, been minimized as far as possible. Thus it is believed to be sufficient to designate the upper and lower volcanic rocks of the Tertiary, simply as Upper and Lower Miocene of the Kamloops sheet, rather than to affix to each of these series of rocks some local name.

Thickness of
rock-series.

It is further to be noted, that the maximum observed or estimated thickness is given in each case in the table. But it by no means follows that this always represents the actual maximum thickness, for in several cases there is reason to believe that the volume of strata, if accurately known, would much exceed the figures given. On the other hand, cases are not wanting in which a very small thickness of beds appears as the representative of what is elsewhere a very massive series. This is particularly found in the volcanic rocks of the Tertiary, where, in some instances a single flow of basalt spread over the surface of the older rocks is all there is to show for the more than 3000 feet elsewhere representing the Upper Miocene.

Again, in the case of the Cambrian rocks—the whole thickness of these actually known by sections in the Kamloops sheet is about 11,500 feet only, but in the sections on Adams Lake the volume of the upper member of the Cambrian alone is about 17,000 feet. These sections are so closely related to those of the Kamloops sheet that there can be little doubt that the entire thickness of the corresponding beds in it would be found to be nearly the same if fully displayed. It is somewhat different, however, in regard to the lower member of the Cambrian, for the thickness given under this head in the general section is derived from the section in the Selkirk Range, at a considerable distance, and it may very well be that, within the limits of the sheet, the actual thickness of this member is different—possibly less.

Aggregate
thickness.

It will thus be apparent that the vast aggregate thickness of the rocks, amounting to 76,600 feet, need not be supposed to have ever been in any one place superposed as a single section; but it is very clear that, average the thicknesses determined as we may, we have an enormous volume of strata to reckon with in this part of the Cordilleran belt.

Great abundance of volcanic materials.

In a paper read before the British Association for the Advancement of Science in 1880,* the writer pointed out, as one of the most significant facts of the geology of the Cordilleran region, the recurrent accumulation there of great masses of volcanic materials at different stages of the geological scale. Subsequent investigations have served to confirm this indication and to increase its importance, and of this

* Geol. Mag., April and May numbers, 1881.

no better evidence can be given than the general section for the Kamloops region presented herewith. Further corroboration to the same effect, is also now coming in from various sources, as the investigation of the rocks of the Western States of the American Union is being proceeded with in the light of the comparatively recent recognition, for that region, of the existence of volcanic rocks older than those of the Tertiary.

Assuming the section here given to be some index for the Interior Plateau region of British Columbia as a whole, an assumption consistent with the facts already known beyond the particular area of the Kamloops sheet, the writer believes it to be well within the limits of probability to estimate the volcanic materials from (and including) those of the Cambrian at about 20,000 feet in total thickness. In order to give definiteness to our ideas, it may be supposed, as a minimum, that the width of the belt characterized by this development of volcanic rocks is about one hundred miles. It follows, almost inevitably, that so vast an extravasation must have been accompanied by enormous subsidences, and, so far as can be ascertained, the main line of such subsidences must have corresponded generally with the present position of the Coast Ranges. Here, more than elsewhere, it would appear that thousands of feet of strata have been engulfed—forced down by superincumbent additions, or depressed by flexure below the surface till they reached the zone of granitic fusion. But the movement affecting the area of the Coast Ranges has not been continuously one of depression. Recurrent periods of elevation have resulted in the production, at more than one period, of a chain of mountains along this line, which has again more than once been broken down and carried away by denuding forces, till at the present day we find the existing mountains, low in comparison with some of those of the further interior, but consisting for the greater part of granitic rocks of deep-seated origin, with but scanty remnants of the older members of the Paleozoic series resting upon their flanks or remaining as infolds in their mass. Very often, and over large areas along the littoral of these ranges, the beds which rest directly upon the granites are of Triassic age; but from this it is not to be argued that the older formations have never existed there, for these may only have passed beyond recognition by entering as component parts into the subjacent granitic magma.

Extravasation
in Interior
Plateau.

Probable sub-
sidence in
Coast Ranges.

PERIOD.	SPECIAL NAMES OF GROUPS OR FORMATIONS.	CHARACTER OF THE ROCKS.	Approximate observed or estimated thickness in feet.
KAIKOZÖIC.	<i>Early Pliocene?</i>	Conglomerates	3,100
	<i>Later Miocene.</i>	Volcanic rocks, largely basalt.	1,000
	<i>Earlier Miocene.</i>	Bedded tuffs	5,300
	<i>Oligocene.</i>	Volcanic rocks, largely porphyrites.	9,400
	<i>Earlier Cretaceous.</i>	Conglomerates and sandstones.	5,000
MESOZÖIC.	<i>Triassic (and Lower Jurassic.)</i>	Sandstones, conglomerates and argillites.	7,000
		Chiefly volcanic, some limestones and argillites, 7,500 to	13,500
	<i>Upper Paleozoic</i> (Chiefly Carboniferous.)	IN WESTERN DISTRICT. <i>Upper part.</i> — <i>Merle Canon limestone</i> , with some volcanic rocks, argillites and quartzites. <i>Lower part.</i> —Argillites, quartzites and volcanic rocks with some limestone.	3,000
		IN EASTERN DISTRICT. <i>Campbell Creek beds</i> (?) a. argillites and amphibolites, about Argillites and gneisses, limestones and volcanic rocks	6,500
PALÆOZÖIC.		Chiefly volcanic rocks with some arkose conglomerate. Thickness actually observed in Kamloops sheet, 9,500. Total thickness in adjacent Adams Lake section	5,000
	<i>Lower Paleozoic.</i> (Chiefly Cambrian.)	Chiefly dark argillites. Thickness actually observed in Kamloops sheet, 2,000. Total thickness in Salix Mountains section	7,500
			17,100
			15,000
			32,100
			79,500

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GENERAL GEOLOGY.

In the following pages a brief general outline is given of the character and relations of the several formations under which the rocks of the district are classified.

Cambrian.

It has of late years become evident, that rocks of the Cambrian system have a great extension in British Columbia, and are, at least in some places, developed in enormous thickness. No direct evidence of the age of the rocks classed as Cambrian within the area of the Kamloops sheet has, however, been obtained within the limits of the sheet, and their recognition here depends on several intermediate terms, by which they are connected with the great Cambrian series as developed in the corresponding part of the length of the Rocky Mountains proper. To make this clear, it will be necessary to enter into some short explanation of the facts. These rocks, with others believed to be Archæan, constitute a great part of the section examined in 1877 on the Shuswap Lakes, of which some account is given in the report for that year (p. 96 B et seq.), but respecting the age of which nothing could be said definitely at that time.

Evidence of
Cambrian age
here indirect.

In 1888, an examination of the shores of Adams Lake, a body of water thirty-seven miles in length which lies to the west of the Great Shuswap Lake, afforded a better and less complicated section than had previously been obtained of rocks of the same old series. In 1889 similar rocks were again found and studied in the vicinity of Kootanie Lake. The lower or presumably Archæan series was there recognized, as well as a great thickness of overlying rocks, comprising black micaceous argillites, followed above by green and gray schists. The rocks here met with were evidently the same with those previously known on Shuswap and Adams lakes. In the report made upon the West Kootanie region, a general section was given, combining the results of work in this region with those obtained up to that time on the Shuswap and Adams lakes, and the several rock-series were distinguished under the provisional names of Shuswap (Archæan), Nisconlith and Adams Lake (Cambrian) series. It was also stated that "The gray and greenish schistose rocks [of Kootanie Lake] constituting the second group may, with confidence, be affirmed to be essentially composed of altered volcanic materials, and their present

Rocks of
Adams,
Shuswap and
Kootanie
Lakes.

15,000
\$2,100
79,500

Chiefly dark argillites. Thickness actually observed in Kamloops sheet, 2,000. Total thickness in Selkirk Mountains section

Nisconlith Series.

schistose character may probably be regarded as in the main due to the enormous pressure to which they have been subjected during the movements of the earth's crust, which resulted in the uplift of the mountains of the region and the extrusion of the great masses of granite here everywhere found.*

It was further noted, in the same report, that although some evidence of this change dependent on dynamic metamorphism occurred in the Kootanie district itself, the best evidence upon this point had been obtained in the region between Adams and Shuswap Lakes and the North and South Thompson rivers; the allusion here being to part of the district adjacent to the eastern edge of the Kamloops sheet which had been examined in the previous year.

Similar rocks
in the Selkirk
Range.

Having arrived at this point, it became eminently desirable that a connection should be established between the older rocks of the Interior Plateau of British Columbia, the Gold Ranges and the western flanks of the Selkirk Ranges, and those to the eastward, in the Rocky Mountains proper, which had already been carefully examined along the Bow River Pass by Mr. R. G. McConnell, and reported on by him in 1887.† Thus in the autumn of 1890, an examination was made by the writer, on the line of the Canadian Pacific railway, across the whole width of the Selkirk Range. As a result of this examination of the intermediate region, it became possible to establish a fairly satisfactory correlation of the different developments of these older rocks, and of this a short review was given in a paper read in December, 1890, before the Geological Society of America, in which a comparative table was also presented of the rocks as found:—(1) On Kootanie and Adams Lakes.‡ (2) In the Selkirk Range on the line of Canadian Pacific railway, and (3) on the west side of the Rocky Mountains, as observed by Mr. McConnell.

These forming
a connecting
link.

The comparison thus instituted rendered it possible to correlate a large part of the rocks previously observed on the Kootanie, Shuswap and Adams lakes, as well as a part of those of the Interior Plateau of British Columbia, with the recognized Cambrian strata of the Rocky Mountains proper. It is, however, in the last-mentioned section alone, that any palaeontological evidence is available by which to fix the pre-

*Annual Report, Geol. Surv. of Can., vol. IV. (N.S.), p. 30 B.

†Annual Report, Geol. Surv. of Can., vol. II. (N.S.)

‡Bull. Geol. Soc. Am., vol. II., pp. 165-176. In the table there given, as well as in that given in the report on the West Kootanie district above alluded to, the thickness of the Adams Lake series and its overlying beds was, by an error in the scale, made just one-half too small. This error is corrected in the table accompanying the present report.

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cise age of the strata, and the correlation made between these rocks of the Rocky Mountains and those of the further western region, necessarily proceeds upon lithological and stratigraphical grounds.

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In order, therefore, to justify the inclusion of a portion of the rocks met with in the area of the Kamloops sheet under the Cambrian, it becomes necessary to refer to the intermediate terms by means of which they are connected with those of the Rocky Mountain section. This will be most easily accomplished by reproducing, with such changes and corrections as have since become necessary, the comparative table which formed a part of the paper last referred to.

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Before proceeding to speak particularly of the Cambrian rocks of the table, it must be noted that the beds included in the upper compartments of two of the three columns, are not known to be equivalent in any strict sense. They are so placed, only because they follow the rocks here described as Cambrian in ascending order. Thus these beds in column 1, very probably belong in large part to the Carboniferous formation, while the age of those occupying a corresponding position in column 3 is much greater, as known by their contained fossils.

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In explanation of the table, the following general notes may be given, extracted wherever included between quotation marks, from the paper already referred to.*

The first column of the table represents the rocks met with in the western part of the Selkirk and Gold ranges, chiefly in the vicinity of Adams Lake, the Shuswap Lakes, and on Kootanie Lake. The lowest rocks in this column, the Archean, were found best displayed on Kootanie Lake, and the thickness given is derived from the part of this system exposed there. The thickness and description of the overlying Cambrian divisions are practically those of the actual section measured on Adams Lake, or in its immediate vicinity.† These rocks run into the eastern part of the Interior Plateau of British Columbia, the section above the Fish-trap Rapid on the North Thompson (see p. 107n.) being directly connected along the strike of the rocks with Adams Lake.

"The third column in the table represents Mr. McConnell's published section in the Rocky Mountains proper, in which certain horizons, ranging upward from the Lower Cambrian, are definitely fixed by fossils. It was found, in working out the section in this part of the

* Bull. Geol. Soc. Am., vol. II., pp. 165-176.

† The thickness of these rocks previously given has been corrected, as already stated.

Provisional Comparative Table of Formations met with (1) in the eastern Border of the Interior Plateau of British Columbia (2) in the Selkirk Range, and (3) on the western Side of the adjacent Port of the Rocky Mountain Range.

1. Section on Kootanie and Adams lakes.	2. Section in the Selkirk range or line of Caledonian Folding Railway.	CARRIBIAN.	
		CARRIBIAN.	ARCHÆAN.
6. Greenish and gray schists, with limestone..... 4,000	Fcd. Greenish and gray schists, with limestone..... 4,000 5. Limestone or marble, with black, glossy argillites and some gray schists ... 5,000	Fcd. Dolomites and quartzites..... 1,300 or more. Graptole-bearing shales. Black fissile argillites, with some limestone 1,500	3. Section in the Rocky Mountains (west side of range; McConnell).
4. Chiefly greenish, with some gray schists..... 8,100			
3. Chiefly gray, with some greenish schists..... 17,100			
2. Black shaly or schistose argillite, with some limestone..... 1,000 or more.	Niscomith Schist. Blackish argillite-schists and phyllites, generally calcareous, with some beds of limestone and quartzite..... 15,000	Bow River series. Dark argillites, with some quartzites and conglomerates, the latter particularly toward the summit. Base not seen..... 10,000 or more.	Bow River series.
1. Mica-schists, gneiss and marbles..... 5,000 or more.			

Rocky section of the r occupied only. The pre (Cambrian east east in large and slat any par

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"The (Archae thickne and ge various schists. sometim mica or due to usually black quartzite pyrites

Rocky Mountains, that a considerable difference exists between the section of the eastern as compared with that of the western part of the range, the present width of which (whatever that originally occupied by the rocks composing it may have been) is about sixty miles only. The particular feature of this change which is interesting in the present connection, is that observed in the Castle Mountain (Cambrian and Cambro-Silurian) group, which although it is on the east essentially a limestone formation, is found on the west to consist in large part of greenish calc-schists and greenish and reddish shales and slates. No granitic rocks or true crystalline schists are seen in any part of this section."

The section represented by the middle column in the table is that found along the line of the Canadian Pacific railway in the Selkirk Range. "It occupies, geographically, as it does in the table, a position intermediate between that of the eastern border of the Interior Plateau and that of the Rocky Mountains. In this, as in the section given in the first column, no horizons have yet been fixed palæontologically, and the position given to the rocks therefore depends principally on the comparison of the section with that known in the Rocky Mountains proper. It is probable, from the composition and condition of the rocks that they may be found to hold fossils; but in the meantime it is believed that the lithological resemblance of the formations to those met with in the Rocky Mountains, is in itself sufficient to enable some important general conclusions to be arrived at respecting the rocks of the Selkirk Range, while the analogy of the rocks of the Selkirks to those of the first section is also such as to afford some clue to the age of the formations represented in it."

Column 2 of Table.

"*The Nisconlith Series.*—Overlying the basal holo crystalline (Archæan) series in the Selkirk section, is a mass of rocks of which the thickness is estimated at fifteen thousand feet. These are dark coloured and generally blackish argillite-schists and phyllites, representing various stages in alteration between true argillites and micaceous schists. The rocks are usually rather finely fissile, with glossy and sometimes wrinkled surfaces, but often with much minute yet visible mica on the division-planes. These planes are in some cases evidently due to cleavage, but are often true bedding-planes. The rocks are usually calcareous, and frequently hold thin layers of dark-bluish or black impure limestone, together with occasional layers of dark quartzite. The coloration is evidently due to carbonaceous matter, and pyrites crystals are very common in certain zones. The only notable

Nisconlith Series.

*Annual Report, Geol. Surv. Can., vol. II. (N.S.), pp. 24 D, 25 D.

diversity met with in the otherwise homogeneous mass of rocks is found towards the base, where (at the lower end of Albert Cañon) a bed of pure blue-gray crystalline limestone thirty feet or more in thickness occurs, and a short distance still lower in the section, a series of beds of over one thousand feet in thickness, consisting chiefly of granular pale gray quartzites. The quartzites are sometimes flaggy and generally more or less micaceous, and are interbedded as well as overlain and underlain by blackish micaceous argillites and layers of coarsely micaceous schists."

"These rocks undoubtedly represent the Nisconlith series of the first column, of which no extended sections have yet been found in the Interior Plateau, while to the eastward they certainly correspond, in the main, with the Bow River series of the Rocky Mountains, for which a thickness of ten thousand feet was there ascertained, though the base of the series is never exposed in the Rocky Mountains."

Selkirk
Series.

"*The Selkirk Series.*—Between the foregoing series and the next overlying mass of beds in the Selkirk section no distinct line of division, even of a lithological character, has been observed, there being, apparently, on the contrary, a considerable thickness of passage beds, in which the dark schists of the lower series alternate with gray glossy schists characteristic of the upper series. The estimated thickness of this overlying series is 25,000 feet; and of its rocks the higher central peaks of this part of the range, comprising Mounts Sir Donald, Macdonald, Tupper, Hermit, Cheops, Ross Peak and others, appear to be wholly composed. Lithologically, it consists of a great volume of gray schists and gray quartzites, which are occasionally somewhat dolomitic. The quartzites probably preponderate, and vary in colour from nearly white to gray and greenish-gray, being seldom dark in tint. They often, however, weather to pale brownish colours and pass into coarse grits and fine-grained conglomerates; and these grits and conglomerates have become more or less schistose in structure as a result of pressure, which has also led to the development in them of much fine silvery mica. The schists vary in colour from pale neutral-gray to greenish-gray, and from dull to silvery and lustrous, being in many cases apparently true sericite-schists."

Representa-
tives else-
where.

These rocks undoubtedly represent, at least in a general way, those of the Castle Mountain group of the Rocky Mountain section, to the eastward. For this group Mr. McConnell ascertained a minimum thickness of 7700 feet, but found reason to believe that its total volume in the western part of the range approached 10,000 feet. They likewise also correspond, in the main, with the rocks previously named

the Adams Lake series, differing from them chiefly in the great development of quartzites and quartzose conglomerates; though the discovery of some thickness of precisely similar quartz conglomerates in rocks of the Adams Lake series, near their typical locality (see p. 108 B) tends to bridge over this difference. Under the circumstances, in 1890, it was thought best to name the series met with in the Selkirk Range the Selkirk series, rather than to affirm a precise equivalency of these rocks either with those of the Adams Lake or Castle Mountain series. In regard to this comparison with the last-mentioned series, "the line indicated between this and the underlying (Nisconlith) series in the Selkirks is based entirely on general lithological differences, while there is every reason to believe that a plane of division drawn to correspond with that between the Castle Mountain and Bow River series in the Rocky Mountains would lie several thousand feet above the recognized summit of the Nisconlith series in the Selkirks. In the Rocky Mountains, the Lower Cambrian (*Olenellus*) fauna is known to be common to the lower part of the Castle Mountain and upper part of the Bow River series; * the separation being there made at the base of the distinctly calcareous upper part of the Cambrian, while certain rather characteristic quartz-conglomerates observed in the upper part of the Bow River series of the Rocky Mountains are paralleled by similar conglomerates which abound in the upper series of the Selkirks. No unconformity has been observed between the upper and the lower masses of strata in either place."

Relations to
Olenellus
fauna.

"Though in the Selkirk section the lower of the two great series which have been described resembles the Nisconlith of the Interior Plateau so closely as to warrant extending the same name to it, the fact that the overlying member of the section differs considerably from the Adams Lake series of the Interior Plateau, while on the other side it probably represents not only the whole Castle Mountain group but also the upper part of the Bow River series of the Rocky Mountains, renders necessary the application to it of a provisional distinctive name. It is therefore proposed to refer to this rock-mass as the *Selkirk Series*."

Selkirk and
Adams Lake
Series.

It is very probable, however, that it may eventually be found possible without inaccuracy, and therefore desirable, to unite at least the Adams Lake and Selkirk series under one of these names.

Regarded as a whole, we find reason to believe that the Selkirk and Nisconlith series of the Selkirk Range, and the Adams Lake and Nisconlith series, further to the westward, constitute local representatives

Great Cam-
brian forma-
tion.

* This fauna is known to characterize several thousand feet of the Castle Mountain series, and has been found as well about 3000 feet down in the upper part of the Bow River series.

of a great Cambrian formation, with an aggregate thickness in both cases of about 25,000 feet. This formation (by analogy with the Rocky Mountain section) includes the lower part of the Cambro-Silurian at its summit and extends, without stratigraphical break, down to, and far beneath, a horizon at which the *Olenellus* or Lower Cambrian fauna has been found.

In the paper from which the above extracts have been made, the following statement was given respecting the change of lithological character of these Cambrian rocks when followed from east to west across the component ranges of this part of the Cordillera:—

Change in
lithological
character.

"The comparatively pure limestones of which the Cambrian of the eastern part of the Rocky Mountains is composed are replaced in the western part of that range by rocks largely clastic in origin. This change in lithological character appears to continue, and to become still more marked and to be accompanied by increasing thickness in the Selkirk Range. Much of the clastic material is siliceous, and the introduction of an increased proportion of such material may be explained by considering it as a result of approach to the shore-line of Archean rocks on the west. While the principal development of contemporaneous volcanic products, whether in the Palæozoic, Mesozoic or Tertiary, is confined to a region west of the local Archean axis, the writer is inclined to believe that a portion of the remarkable difference found to occur in the western extension of the Cambrian, may be due to the inclusion in its rocks, on this side, of volcanic ash deposits or other fine-grained volcanic materials, of which the composition was such as to favour the subsequent production of sericitic or sericite-like schists."

Subsequent investigations appear fully to sustain the view thus advanced, showing as they do that in the rocks representing the Selkirk series in the vicinity of Adams and Shuswap lakes, the preponderance of quartzose clastic material is not maintained, but that green and gray schists which can be traced into diabases, diabase-agglomerates and other rocks of volcanic origin, form the great bulk of these rocks.

Introduction
of volcanic
material.

Thus it would appear, that while the massive limestones of the Castle Mountain series were in course of deposition in the region now represented by the eastern slopes of the Rocky Mountain Range, the calcareous materials became largely intermixed with volcanic detritus and arkose matter further to the west, producing under metamorphism the great mass of calc-schists found in the western parts of that range. In the Selkirk region, local granitic and gneissic shores

supplied great quantities of coarse sediments, while volcanic ash or other material resulting from contemporaneous volcanic action became to a still greater extent a constituent of the rocks. Still further to the west, in the vicinity of the region now occupied by the Gold Ranges, and also apparently to the southward about Kootanie Lake, massive volcanic rocks became entirely preponderant at this time; the quartzose and arkose constituents are sparingly represented and pure limestones are no longer found. Rocks still represented by massive diabases and by diabase-agglomerates, where not affected by great dynamic alteration, are now found in the form of the green and gray schists of the Adams Lake series, and can actually be traced into connection with their massive originals to the west of the flanks of the Gold Ranges. Even here, however, the argillites and limestones of the Nisconlith series continue as the lower number of the Cambrian, representing a period antecedent to that at which the great and evidently long-continued volcanic eruptions of the later Cambrian occurred.

The establishment, by observations in the field, of the fact of the passage of the green and gray schists of Adams and Shuswap lakes into the massive volcanic rocks, has afforded the key to the relations of the rocks of the Interior Plateau region with those of the Gold and Selkirk mountains. Recent observations made in different parts of the world, and particularly the microscopical investigation of certain schistose rocks, have already established the fact that such schists may be produced from old massive volcanic products by means of dynamic metamorphism; but without actual proof of the occurrence of so marked a change in the character of the rocks in this particular region, observations such as those referred to could be accepted only as affording a probable explanation of the conditions here met with. It has been found possible to trace out the change from a massive to a schistose character on the ground and in the large scale. The most direct connection established between the green and gray schists of Adams Lake and the non-schistose greenstones, is that by way of the Cin-max Valley and the lower part of the valley of Louis Creek. From the glossy chloritic sericitic and nacreous schists of the vicinity of Skwam Bay, on Adams Lake, following the general strike of the rocks westward, a gradual transition may be found to the more or less distinctly schistose diabases of the lower few miles of Louis Creek, and from these to the scarcely schistose diabases and felspathic rocks of the east side of the North Thompson above the mouth of Louis Creek.

As the foliation of the schists is thus due to pressure rather than to any originally bedded structure, it may reasonably be questioned whether the thickness of such formations as the Adams Lake series

Foliated and massive volcanic rocks.

Change traced in the field.

Foliation and measurements of thickness.

can be ascertained from observations of the dip of the schists as they exist at present. It must be admitted that this consideration introduces a considerable element of doubt, and in some places it is even quite apparent that the foliation cuts planes representing original bedding at an angle. On the whole, however, with regard to the schistose rocks of Adams Lake, Kootanie Lake and the Selkirks generally, I am inclined to believe, that there is usually a coincidence between the foliation and bedding such as to render estimates of thickness of the kind alluded to fairly trustworthy. The fact that alternations in character of material occur in layers parallel to the foliation, favours the belief, while on Adams Lake, for instance, the difference observed between the generally gray schists of the lower part of the formation and the generally green schists of the upper, shows that there is no bold overturn and repetition of the whole mass of these rocks. It therefore only remains possible, that portions of the same part of the original series of beds may have been locally folded together and compressed in such a manner as to involve a partial repetition of beds. But where this may occur, any increase of thickness accruing is probably more than compensated for by a general attenuation of other parts of the formation which must have resulted from the extreme degree of pressure to which the beds as a whole have been subjected. If this view be correct, it follows that while some undue prominence, which it is impossible to eliminate, may be given to certain classes of rocks in the section, the aggregate thickness and general character of the section as a whole has been little affected.

Area of Cambrian as mapped.

Reverting to the particular area of Cambrian rocks outlined upon the Kamloops sheet, in the vicinity of the North Thompson; it must be confessed that it is not without some hesitation the attempt to define these rocks has been made. Their limit may be said to be drawn entirely on lithological grounds of difference observed between them and the strata adjacent, which are referred to the Cache Creek formation. The area coloured as Cambrian, however, is certainly coextensive, particularly in its southern part, with one of metamorphism much greater than that ordinarily found in the same region, and should it be found necessary in the light of further investigation to change the position of the line, it has, as now drawn, at least a certain value in differentiating this metamorphic area.

It is by no means improbable, as elsewhere stated (p. 109 B), that a considerable tract to the west of the North Thompson and north of Whitewood Creek, should be included with the rocks just referred to, but the balance of the evidence at present appears to me to be against this.

Reference must also be made to the possible existence of Cambrian rocks in the much disturbed and altered western edge of the Palæozoic series in the vicinity of the Coast Ranges, as mentioned on page 43 B.

Newer Palæozoic Rocks—Chiefly Carboniferous.

As the result of his own investigations and those of Mr. James Richardson in British Columbia, concurrently made in 1871, Dr. Selwyn was led to propose two groups (constituting the fourth and fifth groups of his preliminary general section) with the names of Upper Cûche Creek and Lower Cûche Creek respectively, under which he included a large part of the older rocks of the interior of the province. The Upper Cûche Creek group embraced the massive limestones of Marble Cañon and of the Marble Mountains, with some associated "red and green shale, and epidotic and chloritic rocks, with others which closely resemble rocks of the Quebec group in the Eastern townships of Canada." The Lower Cûche Creek group was made to include the cherty quartzites, argillites, greenstones, serpentines and associated limestones found to occur along the Thompson and Bonaparte valleys in the vicinity of the main wagon-road.* It was at this time suggested, because of the occurrence of a foraminifer recognized as of the type of *Lofusina* in the Marble Cañon limestones, that the Upper Cûche Creek group was of Eocene or Cretaceous age, while the Lower Cûche Creek group, on the evidence of the fossils examined by Mr. Billings, was known to occupy a position somewhere between the base of the Devonian and the summit of the Permian.

In reporting on a portion of the northern part of the interior of British Columbia in 1875, the writer assigned some of the rocks there met with to the Lower Cûche Creek group, on lithological grounds alone, for no fossils were discovered in them.† In the following year, as the result of further and more extended work in the same northern region, the peculiarly Carboniferous fossil *Fusulina* was found to be abundant in the massive limestones of Stuart Lake, and these limestones with certain quartzites, argillites and green schistose rocks, were together classed under the Lower Cûche Creek group; while their relations with rocks of the southern part of Vancouver Island and with those of a portion of the Rocky Mountain range, were also pointed out.‡

* Report of Progress, Geol. Surv. Can., 1871-73, pp. 60-62.

† Report of Progress, Geol. Surv. Can., 1875-76, pp. 247-260.

Report of Progress, Geol. Surv. Can., 1876-77, pp. 55, 89.

History of the
Cûche Creek
formation.

Discovery of
Fusulina.

Consolidation
of the Upper
and Lower
Câche Creek
groups.

It will be observed that no rocks referable to the Upper Câche Creek group had been found during the explorations of 1875 and 1876, and when in 1877 a further and more detailed examination was made by the writer of the southern part of the interior of the province, upon which the original classification had been founded, the conclusion was arrived at that the so-called upper and lower groups are not strictly separable on stratigraphical or lithological grounds, while *Fusulina* was found to occur in association with the massive limestones of Marble Cañon as well as in the limestones of the lower group. In the report on the work of the season, the whole of the rocks previously placed in these two groups were referred to under the name of the Câche Creek series,* and further investigations have since served to bear out this consolidation of groups. Thus in the present report, as in that last referred to, the Câche Creek series or formation must be understood to embrace the rocks originally included in the Lower and Upper Câche Creek groups. There can indeed now, I think, be no doubt that the Marble Cañon limestones, which constituted the greater part of the Upper Câche Creek group, are in fact the higher member of the formation, and between these and the underlying rocks it may eventually become convenient to draw a line of division. But important beds of limestone also occur in the lower part of the formation; there is a stratigraphical and lithological interlocking between both parts, and the palæontological evidence, so far as it goes, indicates the reference of both parts to the Carboniferous.

Interlocking
of characters.

It must further be explained that, in mapping the Paleozoic rocks of the area here described, it has been found practically impossible to separate the rocks originally spoken of as the Anderson River and Boston Bar group† from those of the Câche Creek formation. Dr. Selwyn was, at the time he proposed this name, unable to assign any age to these rocks, but the order of the group in his report shows that it was understood to lie below the Câche Creek formation. This reference proves to be a correct one, for it can now scarcely be questioned that these rocks either underlie the greater part of the rocks classed as the Lower Câche Creek group, or correspond in part with the lower portion of that group. But while upon the single line of route originally examined, these rocks are widely separated by other groups from those of the Câche Creek formation, the two series have since, in different localities, been traced into connection, and in such places no means have been found of defining a line between these rocks. Some details on this point are given later. (p. 43 B.)

* Report of Progress, Geol. Surv. Can., 1877-78, p. 169 B.

† Report of Progress, Geol. Surv. Can., 1871-72, p. 62.

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The C che Creek formation, as shown on the present map and as now understood, must therefore be regarded as including a very thick series of Pal ozoic rocks, of which the greater part is definitely referable to the Carboniferous period by means of its fossils, but of which it is scarcely probable that the upper and lower limits agree precisely with those of the typical Carboniferous. It may very possibly be found at the base, particularly, to transgress these limits and to include beds older than those of that system.

In attempting a brief general description of this formation, it must in the first place be observed that the extremely broken and disturbed character of its rocks, almost everywhere renders it next to impossible to learn much about their attitude or sequence in any one locality. It is very generally impossible to determine whether the dip of the beds is normal or has been overturned. It is thus only by following the general association of the rocks from place to place and by piecing together facts observed at many different places that it becomes practicable to outline the salient features of the whole.

The western part of the Kamloops sheet, between the Thompson and Bonaparte rivers on one side and the Fraser on the other, is the typical area for the C che Creek formation, and the most definite feature which can be traced throughout, is the belt of massive limestones already several times referred to. Beginning to the north in the Marble Mountains, these gray and whitish limestones, sometimes marbles, are continued in the Pavilion Mountains, cross Marble Ca on, and after an interval in which they are concealed by Tertiary rocks, reappear in the western part of the Cornwall Hills, extending southwards to White Mountain and to Blue Earth Creek. Further south the Tertiary volcanic rocks are continuously spread across their line of strike.

Practically the entire mass of the Marble Mountain range is composed of these limestones, as well as the whole eastern part of the Pavilion Mountains. They include comparatively insignificant intercalations of argillite, cherty quartzite and materials of volcanic origin. Further south, in the region to the east of Hat Creek, such materials become more abundant and form thick beds among the limestones, particularly the cherty quartzites and the green stones. In this region it is probable that the lower part of the great limestone series is most prominently displayed, and that higher beds are more characteristic in the north, particularly in the Marble and Pavilion Mountains. The earlier stages of the great period of limestone deposition appears to have been marked by frequent interruptions, during which argillaceous and

C che Creek formation defined.

Its shattered character.

The marble Ca on limestones.

Character of the rocks.

volcanic products were laid down ; while in its later stages, the deposition of limestone must have been almost unbroken. The interlocking of the different classes of materials is such, however, as to show the close connection which obtains between the Marble Cañon limestones and the lower parts of the C  che Creek formation.

A great syncline.

The limestone belt above described, has, within the limits of the map, a length of above sixty miles. There can now be no doubt that this represents a great syncline, upon both sides of which the older members of the C  che Creek formation are displayed ; but superimposed upon this general structure are very numerous smaller folds, which generally run in more or less exact parallelism with it, but often in varied directions. The limestone has thus been, as it were, heaped together by repeated folding, in such a manner that it occupies a width much greater than that which can possibly be due to its thickness, with the high dips which are usually found. Similar complex folding affects the underlying rocks of the formation, and it is due to this fact that it is almost impossible to obtain any good estimate of its total thickness or of that of its parts. This folding is not generally of the tightly compressed and linearly direct kind met with in, and near, the mountains of the Coast Ranges, but is just sufficiently irregular to make it very difficult to follow. Occasional instances are also found—as for example on the upper part of Jack's Creek, between the Thompson and Hat Creek and in Glen Hart—where the rocks rest at very low angles ; but these are in immediate contact with others in which the same beds are found to be nearly vertical.

Minor irregularities.

Lower members of the C  che Creek.

In speaking of the lower part of the C  che Creek formation, it will be convenient to refer first to the rocks on the east side of the main syncline, near the Thompson and Bonaparte ; next to those lying to the west of the syncline, and last to those in the neighbourhood of the North Thompson and in the eastern part of the map generally.

Along the Thompson and Bonaparte, these lower rocks characterize a belt of country some forty-five miles in length. They consist of cherty quartzites, volcanic materials, argillites and limestones about in the relative order of importance in which these are named.

The 'cherty quartzites.'

The rocks which are for the sake of brevity spoken of throughout as 'cherty quartzites,' are of a somewhat peculiar character. They generally occur in well defined beds of a few inches only in thickness, and often form great masses of strata. They are very fine grained, resembling hornstone or chert, usually gray in colour, passing to black in one direction and to yellow-gray and nearly white in the other, but occasionally greenish-gray. Almost everywhere they are traversed by

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innumerable veinlets and threads of white quartz. The bedding planes are often black and lustrous, and black glossy argillite-schist is frequently associated with them. These rocks have evidently been silicified subsequent to their deposition, but perhaps very soon after, for it is pretty clear that they were much in their present condition before the main period of disturbance by which the formation has been affected. Their microscopic structure throws very little light on their original character, but they have in all probability been laid down as argillites or silts. It is worthy of remark that they closely resemble in their character cherty or hornstone-like rocks found in different parts of the world in association with contemporaneous volcanic beds, affording ground for the belief that their condition may be connected with the circumstances of volcanic action.

It may be mentioned here that cherty beds, which may be of a True cherts. different character, are not infrequently found in the limestones of all parts of the formation. These are often lenticular, and it is quite probable that many or all of them may represent original siliceous concretions of the nature of flint.

The volcanic materials comprise contemporaneous effusive rocks, agglomerates or breccias and ash rocks or tuffs. The effusive rocks generally vary in colour from dark gray-green to green. They are usually rather fine-grained, and on microscopic examination are found for the most part to be very much decomposed diabases in composition. The coarsely porphyritic and uralitic diabases, so abundant in some parts of the Nicola formation, were scarcely seen. The agglomerates are made up in the main of fragments of the same character. The ash rocks and tuffs are often gray, but sometimes green, and when fine-grained it is difficult to separate them by the eye from the traps proper. Where they have been locally subjected to great pressure, the effusive rocks tend to pass into green schists, the agglomerates into rough gray schists, and the ash-rocks into gray speckled schists, in which the constituent particles are often drawn out into linear forms. Rocks of volcanic origin.

With the volcanic rocks, the serpentines, which form a characteristic Serpentines. feature in this lower part of the formation, must be included. They are often seen to be closely associated with the agglomerates and decomposed diabases, and have evidently resulted from the alteration of some highly basic volcanic rock.

The argillites are generally hard and dark coloured, ranging from Argillites. black to gray. They are often schistose, and sometimes show more or less slaty cleavage. In some places they are largely siliceous, and

evinced a tendency to pass into the cherty quartzites. In the black varieties, graphitic or anthracitic carbon appears to be present.

Fusuline
limestones.

The limestones found in the lower part of the formation, to the east of the main syncline, are seldom more than a few hundred feet in thickness and often much less. They frequently prove on microscopic examination to be composed chiefly of crinoidal debris, but often contain *Fusuline* and other foraminifera, as well as fragments of polyzoa and molluscs.

Rocks east of
main syncline.

The cherty quartzites and argillites appear to constitute the bulk of the lowest part of the formation as displayed in this region, while volcanic rocks with associated limestones preponderate higher in the series, in that part of it which approaches the base of the Marble Cañon limestones previously described. The volcanic rocks, with limestone, occupy a considerable area near Cattle Valley, McLean Lake and Medicine Creek.

West of main
syncline.

To the west of the main limestone syncline, the lower rocks of the Cache Creek formation come to the surface in the Edge Hills and their vicinity and in the western part of the Pavilion Mountains and Mount Martley. In their general character the beds here represented are much like those on the east side of the syncline. Argillites, generally schistose, are somewhat more abundant, and the typical cherty quartzites are not quite so well represented. The intercalated limestones appear to be somewhat less important, while rocks composed of volcanic materials are not found immediately beneath the massive limestones in so great volume as before, but appear to be rather more important at a somewhat lower horizon, which crosses the lower part of Pavilion Creek and is found with identical characters along the Fraser above Leon Creek. As a whole, the rocks are somewhat more altered than before. The argillites are more distinctly schistose, and the limestones are more often crystalline and marble-like.

Development
west of Fraser

Further to the south, and west of the Fraser, rocks of the same character, and believed to be of the same age, are found in the vicinity of the town of Lillooet, extending along their strike to In-ti-pam Creek, and again seen on In-koi-ko Creek. They consist here of schistose and slaty argillites, cherty quartzites, well bedded decomposed diabase-tuffs and serpentines. These being included in the eastern strict folds of the Coast Ranges, are all somewhat more notably schistose than elsewhere, but show no other important points of difference.

Somewhat further back from the line of the Fraser, on Cayoosh Creek, Texas Creek and in the higher parts of the Askom Mountain, as elsewhere described in greater detail, the rocks become indistinguishable

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in character from those of the Boston Bar series of the original (1871) scheme. On the assumption that these last-mentioned rocks might be of Cambrian age, an attempt was made to define a line which would separate them from those referred to the C  che Creek formation, but it proved to be impossible to draw any such line to accord with the facts, and the points of difference successively relied upon have broken down under investigation. The only notable and easily observed difference, is one dependent on the more schistose and slaty character of the rocks, which gives to them when examined in the field, a different general aspect. But this difference manifestly depends on the amount of compression to which the rocks have been subjected as infolds in the granitic masses of the Coast Ranges. It is in fact an extreme stage in the transition of which the earlier steps have already been referred to. Fundamentally the composition of these rocks, as well as that of the Boston Bar rocks in their typical locality, further south, is the same with that of the lower part of the C  che Creek formation on the Bonaparte and Thompson. Argillites, altered diabases, ash rocks (though now often passing into chloritic and epidotic schists and porphyroids), and limestones are equally present in both. Cherty quartzites are much less abundant in the Boston Bar rocks, but they are still to be found, and it will be remembered that the present character of these rocks is probably an adventitious and subsequent one. Even the serpentines may be represented by the talcose rocks which occur in some parts of the Boston Bar series.

Attempts
to separate
C  che Creek
and Boston
Bar rocks.

It is true that the present appearance of the Boston Bar rocks and their representatives within the Kamloops sheet is much like that of the lower rocks of the Cambrian, as found for instance in the section near Fish-trap Rapid. (p. 107 B.) This indeed led to the attempt to correlate the Boston Bar rocks with that formation; but against this theory, it may be remarked that the great superior thickness of volcanic materials characteristic of the upper part of the Cambrian in the section near Fish-trap Rapid and elsewhere, is not found in association with these rocks in the Coast Ranges, while the state and mode of alteration of the other rocks may well be accounted for by local causes, and would have affected equally any rocks similar in composition which existed there prior to the great period of folding and uplift of the Coast Ranges.

Resemblance
of Boston Bar
rocks to Cam-
brian.

No pal  ontological evidence is available for the rocks of the Boston Bar series, and as already explained, no attempt is made in this region to draw any hard and fast line as that of the base of the

No fossils
found.

Câche Creek formation. It is quite possible that some part of these rocks may belong to horizons much lower than that of the Carboniferous, but in the present state of knowledge there appears to be no escape from the decision to unite them, at least provisionally, with the Câche Creek formation.

Auriferous character.

One point of particular interest with respect to the schistose and slaty rocks of the Boston Bar series and their representatives in the area of the present map, is their auriferous character. This feature is returned to on a subsequent page.

Rocks near North Thompson.

Turning now to the rocks of the Câche Creek formation, which are shown on the map to occur in the vicinity of the North Thompson—These rocks are found, on the lower part of that river, to be associated with limestones known by their fossils to be of Cambrian age, but they are widely separated from their representatives in the western part of the map, between them and which no single connecting link exists within the area here reported on. Thus, besides the scanty palaeontological evidence, we have only lithological characters upon which to rely. We find here a great series of argillites, often highly siliceous (but seldom with the hornstone-like characters of the typical cherty quartzites), with limestones, grauwacke sandstones, conglomerates and contemporaneous greenstones. These, there is every reason to believe, represent the lower part of the Câche Creek formation, or some portion of it. How far the series may extend downward, there is no means of ascertaining, but in so far as original similarity of composition may be taken as a guide, there appears to be some reason to believe that part of the local development may represent the rocks of the Boston Bar series.

An area of doubtful age.

To the west of the northern part of the North Thompson included by the map, a considerable tract of country is characterized, in so far as it has been possible to examine it, by dark schistose rocks, in part consisting of finely micaceous argillites and in part of rocks which may originally have been volcanic in origin, some of which show points of resemblance to the Campbell Creek series, subsequently described. No limestones have been found in association with these rocks, and although they have been provisionally included in the Câche Creek formation, this reference is very doubtful. Lithologically they are not unlike some of the Cambrian schists of the lower part of the Fish-trap Rapid section.

Campbell Creek beds.

To the south of the line of the South Thompson, on Campbell Creek, near Douglas Lake and elsewhere in the south-eastern part of the map, the series of rocks designated as the Campbell Creek beds occur.

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These amphibolites are apparently a separate section about the character, which it appears to be a zone. The Cambrian of the Câche Creek Nicola formation has been described, facts, to mention, and part of it is to that extent in the eastern part.

As elsewhere, it breaks out in the Nicola formation, factorily at the junction on the North Thompson, and it is the Campbell Creek formation, graphically recognizable in relation to the argillites that the series is based upon.

On the limestone part of this fact, stone has part of the

* See R.

These consist of dark argillites and fine-grained, bedded, black, slaty amphibolites, with some layers of grauwacke sandstone and some apparently interbedded masses of green uraltic diabase. With the exception of the amphibolites, these rocks closely resemble those found about the North Thompson, but this exception is of so marked a character, while the distance separating the localities is inconsiderable, that it appears necessary to assume it to mark some difference of horizon. The circumstances of their occurrence render it evident that the Campbell Creek beds must belong either to the upper part of the C  che Creek group, as locally developed, or to the lower part of the Nicola formation; for it is clear that these beds hold a position stratigraphically intermediate between the two formations named. It has been decided to be most in accord with our present knowledge of the facts, to include the Campbell Creek beds with the C  che Creek formation, and thus the thickness of 'this series of beds,' (or at least a great part of it, for there may be some overlap of horizons) should be added to that estimated for the C  che Creek formation on the North Thompson in order to represent the total volume of that formation in this eastern part of the map.

Provisionally
assigned to
C  che Creek.

As elsewhere explained, there is some appearance of a passage without break between the Campbell Creek beds and the lower beds of the Nicola formation, for no really definite line has yet been satisfactorily determined between them. In the case of the unconformable junction of the C  che Creek rocks with those of the Nicola formation on the North Thompson, not far to the east of the margin of the present map,* no rocks resembling the Campbell Creek beds are found, and it is therefore probable, to which ever of these formations the Campbell Creek beds may ultimately be attached, that the stratigraphical break at this place is an important one. Neither are recognizable representatives of the Campbell Creek beds found in the section to the south of Ashcroft (p. 112 B), but the distance which separates this from the typical localities of these beds is so considerable that the argument for unconformity by overlap, which might there be based upon this circumstance, is less cogent.

Campbell
Creek beds
absent to the
west.

On the other hand, no trace of the massive upper or Marble Ca  on limestone of the C  che Creek formation as represented in the western part of the map, has been found in the eastern part. To account for this fact it may be conjectured: (1) That if deposited here this limestone has since been removed by denudation; (2) that the upper part of the formation has no representative in this region; (3) or that

Marble Ca  on
limestones ab-
sent to the
East.

* See Report of Progress, Geol. Surv. Can., 1877-78, p. 30 B.

it is represented by other rocks, as for instance by the Campbell Creek beds.

The amount of pre-Triassic denudation implied by the first hypothesis is so great that considerable hesitation is felt in adopting it. The abundance of graywackes and the occurrence of some conglomerates in this eastern part of the C  che Creek formation, appear on the other hand to suggest the occurrence of an approach to littoral conditions, which would favour the acceptance of one or other of the two last named hypotheses.

Probable total
thickness of
C  che Creek.

The extremely unsatisfactory condition of the rocks of the C  che Creek series for all purposes of measurement, will be understood from the foregoing remarks as well as from the further local details given on later pages. Thus, in endeavouring to give some idea of the total volume of the formation, no even proximately correct data can be quoted. The subjoined summarized section is therefore merely an attempt to indicate the general order of succession, and to some extent the importance of the formation, in the western part of the area of the map. The order is descending :

	Feet.
1. Massive limestones (Marble Ca��n limestone) with some minor intercalations of volcanic rocks, argillites and cherty quartzites. At least 1000 feet seen in some single exposures. Total thickness probably at least	3,000
2. Volcanic materials and limestones, with some argillites, cherty quartzites, etc. Minimum thickness about	2,000
3. Cherty quartzites, argillites, volcanic materials and serpentines with some limestone. The thickness of these beds, or of a part of them, was roughly estimated in two places as between 4000 and 5000 feet. Minimum total thickness say	4,500
	9,500

The thickness of the lower members of the above section depends upon their development on the east side of the main limestone syncline. It will be remembered that the character of the rocks is somewhat different on the west side, where, in particular, the volcanic materials do not appear to be so important immediately below the Marble Ca  n limestones, though perhaps more largely developed at a somewhat lower stage.

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To the south of the area of the present map, the thickness of the rocks included in the typical Boston Bar group of the original classification alone, is estimated at between six thousand and seven thousand feet (p. 102 B). The thickness of the beds referred to the C che Creek formation on the North Thompson, is roughly estimated as about seven thousand five hundred feet (p. 104 B), but, if as above indicated a considerable part—say five thousand feet—of the Campbell Creek beds may be added to this, we obtain a total volume of twelve thousand five hundred feet for the C che Creek formation in the eastern part of the map.

Thickness of
Boston Bar
group.

Thus, the entire volume of the rocks of the C che Creek formation as this is now defined, may be assumed to be about ten thousand feet as a minimum, while I am inclined to believe that it really exceeds fifteen thousand feet.

The existence of rocks referable to the C che Creek formation in the northern parts of British Columbia has already been alluded to in connection with the general definition of the formation. These rocks have in fact now been found to occur at intervals from the southern boundary of British Columbia north-westwards to the upper waters of the Yukon, characterizing particularly a belt of country which lies to the east of the Coast Ranges, and which corresponds more or less closely with the Interior Plateau of the southern part of the province. Their lithological composition, throughout this length of over 800 miles parallel to the general structure of the Cordillera, is everywhere much the same; massive limestones, cherty quartzites and volcanic products being characteristic.

C che Creek
rocks in North-
ern British
Columbia.

A few characteristic fossils have been obtained in a number of places beyond the limits of the present map. At Stuart Lake (lat. 54° 30'), Dease River (lat. 59° 15'), Frances River (lat. 60° 30') and on Tagish Lake (lat. 60°), fusuline limestones have been observed.

To the westward of the Coast Ranges (in which it is probable that numerous infolds of Pal ozoic rocks will yet be found) a formation known from its fossils to be of Carboniferous age is again well represented. This has, so far, not been very minutely examined or reported on in detail, but it is known to comprise thick beds of limestones, argillites and volcanic materials, the latter being even more characteristic and in greater development than in the region here specially dealt with.*

On the coast.

In the Rocky Mountains proper, or eastern member of the Cordilleran system, the section which must now be regarded as the typical

Carboniferous
of the Rocky
Mountains.

* See Geol. Mag., dec. II., vol. VIII., pp. 218, 219.

one for these latitudes, is that worked out by Mr. R. G. McConnell.* In this section the Carboniferous period is represented by the Banff limestone series which, including two shaly zones, has a thickness of 5100 feet.† This has yielded a number of fossils, and these show that the series as a whole represents the lower part of the Carboniferous, passing below into Devonian-Carboniferous. The later part of the Carboniferous period seems either to be unrepresented, or if represented at all, to find but a partial equivalent in the upper shales. It is thus very probable that before the close of the Carboniferous the present position of the Rocky Mountains formed part of a land area.

Region between Kamloops area and Rocky Mountains.

Thus, the absence of the great Marble Cañon limestones of the C  che Creek formation in the eastern part of the Kamloops sheet, with the appearance already noted of an approach there to littoral conditions, may indicate that this land area of the later Carboniferous extended westward nearly or quite to the eastern edge of what is now the Interior Plateau region. It must, however, be noted, that in some portions of the region between the Kamloops sheet and the Rocky Mountain range, as on Adams Lake and Kootanie Lake, the upper part of the general section includes thick beds of limestone, with greenish and gray schists and black argillites, which are believed to be at least in large part referable to the Carboniferous period.‡ But it is not known to what part of the Carboniferous these belong, and it may very well be that they more nearly represent the horizon of the Banff limestones than that of the Marble Ca  n limestones of the C  che Creek formation.

Carboniferous rocks of California, etc.

Carboniferous rocks closely resembling those of the western part of British Columbia will probably eventually be found in the corresponding western portions of the States of Washington, Oregon and California, where limestones of this age have long been known in a number of localities. Mr. J. S. Diller has lately described the occurrence of important volcanic intercalations in the Carboniferous rocks of the Taylorville region of California, thus bringing these into line with the long recognized character of the Carboniferous of British Columbia in this respect. He finds reason to include (though in part doubtfully) a thickness of over fifteen thousand feet of beds in this system at that place.§ Further east, in the Middle Nevada and Wahsatch sections, Clarence King has found the Carboniferous system

* Annual Report, Geol. Surv. Can., vol. II. (N. S.)

† *Op. cit.*, p. 17 D *et seq.*

‡ See p. 29 B, also Annual Report, Geol. Surv. Can., vol. IV. (N. S.), p. 31 B.

§ Bull. Geol. Soc. Am., vol. III., pp. 372, 374-376.

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to consist, in descending order, of the (1) Upper Coal Measure limestone, two thousand feet, (2) Weber quartzites, six thousand feet, and (3) Wahsatch limestones, seven thousand feet, with a total thickness of fifteen thousand feet, the lower portion of the last named formation passing down, however, into the Devonian.* With our present information, it would appear that the Marble Cañon limestones probably represent the upper member of this section, while the lower parts of the C  che Creek formation are equivalent in a general way to its two lower members.

It has already been noted that the lower portions of the C  che Creek formation may be older than the Carboniferous period. The very general blending of the Carboniferous and Devonian systems in the West, shows that no well-marked line need be anticipated at the base of the Carboniferous. The separation of any beds of Devonian age can only be made in the event of the future discovery of characteristic fossils. The same may be said respecting the possible existence of Silurian or Cambro-Silurian beds. Where complete sections have been examined in the western parts of the continent, these usually form a comparatively thin series, intervening between the Cambrian and the Devonian-Carboniferous, both of which are very massive formations. In a great mass of strata like that here reported on, there is ample place for such representatives of these rocks, but so far, in the southern part of British Columbia, no fossils of this age have been detected to the west of the Rocky Mountain range. In the far north, however, on the Dease River (Lat. 59° 45') graptolites of Cambro-Silurian age have been found.†

Possible occurrence of Devonian Silurian, etc.

Triassic.

Stratigraphy and General Relations.—In the Preliminary Report of 1877, the existence of rocks of Triassic age in British Columbia was for the first time made known. The statements then made rested chiefly upon the facts met with in the vicinity of Nicola Lake, and the formation was in consequence named the *Nicola series*. The determination of the age of the rocks depended almost entirely upon the interpretation given to the few fossils obtained from the limestone of McDonald River (Quilchenna Creek) and the relationship established between this limestone and the associated great mass of volcanic rocks. It thus became possible, at that time, to describe the general character

The Nicola formation

* Geology of the Fortieth Parallel, vol. I., p. 248.

† Annual Report, Geol. Surv. Can., vol. III. (N.S.), p. 94 B.

of the series very much in the same terms which might be employed to-day.* Further search has not resulted in obtaining any additional characteristic fossils from this particular limestone, and it may thus be appropriate to quote the original statement made concerning it, as follows:—

Fossils
originally
found.

"The limestone of McDonald's River, Nicola Lake, was at first supposed to be Carboniferous, but the most diligent search failed to bring to light any characteristic forms of this age, and, on the contrary, resulted in the discovery of the scattered joints of a crinoidal column, closely allied to *Pentacrinites asteriscus*, Meek, of the Jurassic of the Black Hills. It differs from this form, however, in some particulars, but in these it approaches to, and is probably conspecific with, a *Pentacrinites* doubtfully referred to *P. asteriscus* by Hall and Whitfield, and procured from beds of Triassic age in the Pah-Ute Range of Nevada.† Apart from other considerations, this might form a rather uncertain criterion of age, but in the same limestone a *Terebratula* also occurs which can be referred, with very little doubt, to the rather variable species *T. Humboldtensis*, which is also found in association with the crinoid above named, in the same locality in Nevada."‡

The only additional fossil since obtained from this particular locality is one described by Mr. Whiteaves as a species of *Cyrtina* or *Spiriferina* with a very high area, not specifically determinable.

Later discoveries of
fossils.

In 1890, another fossiliferous locality was found in the limestones which outcrop near the mouth of the Deadman River, the collections made including two species of Pelecypoda, not determinable, and portions of the guard of a slender Belemite which might be referred to the Triassic period or to one somewhat later. In the same year, in the hills a few miles to the eastward, and at a horizon which appears to be several thousand feet higher than the last, some fossiliferous argillites were discovered. Professor A. Hyatt, who has kindly made a preliminary examination of the fossils obtained from this and a few other localities, designates these as distinctly Triassic, enumerating a *Myacites* like *M. Humboldtensis*, Gabb, a *Daonella* like *D. Lomaneti*, a *Trigonodus*, a *Cardita* and other fragments.

In 1894, a somewhat minute examination was made of the rocks along the east side of the Thompson, south of Ashcroft, in the course

* Report of Progress, Geol. Surv. Can., 1877-78.

† U. S. Geol. Exploration of the Fortieth Parallel, vol. IV., p. 280.

‡ *Op. cit.* p. 171 B. *Pentacrinites* has since been found in three places in California in association with undoubted Triassic fossils. J. P. Smith. Bull. Geol. Soc. Am., vol. V., p. 260.

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of which fossils were found at two different horizons, separated by about twelve thousand feet of strata. Of these, the lower yielded a *Daonella* like that last noted, and a *Panopea* like *P. Remondi*, Gabb, while the upper is believed by Professor Hyatt to be of Lower Jurassic age, equivalent to the Hardgrove sandstone, and possibly to the Mormon sandstone of Taylorville, California, from which fossils have lately been obtained. Professor Hyatt enumerates two species of *Rhynchonella*, one like *R. gnathophora*, a *Pecten* like *P. acutiplicatus*, Gabb, an *Entolium* like *E. equabilis*, Hyatt MS. and *Lima parva*, Hyatt, MS.

Fossils of
Lower Jurassic
age.

In a small detached area of limestone near the 89-mile stable on the Thompson, a few fossils have also been found to which Professor Hyatt attributes an age similar to the last, although the species represented are different.

The above statements summarize all that is really known respecting the age of the Nicola formation from palaeontological evidence up to the present time. It will be observed that the original reference of the series as a whole to the Triassic has been gradually strengthened by later discoveries. These, taken in connection with the stratigraphy, in fact seem to show that while the great bulk of the Nicola formation is undoubtedly equivalent to the Triassic, it passes up in a few places into rocks of Lower Jurassic date. The structure and lithology do not appear to afford any means of separating the two faunas or of drawing any line through the great mass of rocks, chiefly of volcanic origin, in which they occur, and it is therefore appropriate and necessary to treat of the Nicola formation as a whole, although recognizing the fact that it probably extends higher than the typical Trias.

Strata yielding
these in-
separable from
Triassic.

In several parts of the southern interior region of British Columbia, pretty good evidence exists of an unconformity between the rocks of the Nicola formation and those associated with limestones holding characteristic fossils of Carboniferous age. Such an unconformity is believed to exist in the hills on the north side of the South Thompson, about ten miles above Kamloops and beyond the limit of the present map.* It is also supposed to occur in the rocks near the Thompson River below Kamloops Lake (p. 120 B) and there are indications of its existence in the vicinity of Ashcroft. This unconformity may not, however, be universal, even within the limits of the area here under notice, and the character of the older rocks renders it always very difficult to determine.

Unconformity
with Cache
Creek.

* Report of Progress, Geol. Surv. Can., 1877-78, p. 80 B.

Definition of
the Nicola
formation.

The Nicola group, as originally defined in the report for 1877, was intended to include merely the limestone of McDonald River, with the attached and overlying great series of volcanic materials found in the section on Nicola Lake, as set out on page 77 B of the report cited. Subsequent investigations have, however, shown that greenstone rocks essentially similar to those of the original section, also underlie the McDonald River limestone in the same vicinity, and that they there hold probably at least one other similar thin limestone. These rocks are therefore also now included in the Nicola formation, which here finds its provisional base where they rest upon the dark Campbell Creek beds, already described.

Mapping of
the Nicola.

In attempting to define the limits of the Nicola formation on the map, it has had to be separated from the often lithologically similar rocks of the C  che Creek formation on the one hand, and from those of the Cretaceous and later formations on the other. The latter separation is generally not difficult, but when the Nicola rocks are found in association with some of the altered volcanic products of the Lower Miocene, it is often far from easy to decide upon a line, which must proceed upon lithological grounds alone.

The reasons in accordance with which it has been fixed in each part of its extent, together with the doubts attaching to it, are fully explained in the sequel. As already stated, it is quite possible that a practically continuous sedimentation, or effusion of volcanic products, was maintained in some parts at least of the district throughout the later Pal  ozoic and the earlier stages of the Mesozoic.

Date of gran-
itic rocks.

The more important granitic masses of the region, are evidently later in date than the Nicola rocks, while they are unquestionably earlier than those of the Cretaceous, and their existence and relations to the other rocks frequently affords important information in regard to the upper limit of the Nicola formation. They are probably contemporaneous with some of the larger granite masses found on the coast of British Columbia,* and there can be little doubt that the close of the period of Triassic deposition was brought about by crustal movements either consequent on or productive of the great granitic intrusions of both regions. There is thus undoubtedly a distinct unconformity between the highest members of the Nicola formation and the lowest beds of the Cretaceous, and though this is often more or less masked by subsequent folding and disturbance, it is marked by a distinct change in the character of the materials composing the respective formations,

* Annual Report, Geol. Surv. Can., vol. II. (N.S.), pp. 11 B, 15 B.

as well as by a great limitation of the area of deposition in Cretaceous as compared with that of Triassic times.

The Nicola formation, where it has been recognized, appears to attain its greatest development along the central part of the Interior Plateau of British Columbia. It is most widely spread, and covers a great part of the surface, in a belt of country lying about midway between the inland borders of the Coast Ranges on one hand and the south-western mountains of the Gold Ranges on the other, bounded on both sides by older Palaeozoic formations. But it is very frequently concealed by later Tertiary volcanic rocks, and this is the case particularly in the northern part of the Kamloops sheet.

Area of Nicola rocks.

From what has been said respecting the difficulty of separating the rocks of the Nicola formation from others, it will be understood that while the main outlines shown on the map are believed to be nearly correct, there may be many outliers which have yet escaped definition. Such may very well occur among the flexed and broken rocks of the Cache Creek formation, and it is even probable that some rocks of this series appear in the upper part of the section on Adams Lake and elsewhere in the Gold Ranges, the volcanic materials there being converted into schists, the identity of which can be ascertained only by tracing out their connections with less altered areas.

Boundaries.

Within the area of the Kamloops sheet, the Nicola formation consists essentially of a great mass of volcanic deposits, with a total thickness of probably ten thousand to fifteen thousand feet. In the lower part of the formation, some thin and probably irregular beds of limestone occur. Here and there throughout the formation, a limited thickness of argillites is found, and, forming the summit, so far as yet ascertained, is another bed of limestone.

Composition of the series.

The greater part of the volcanic rocks may be described generally under the useful name of "greenstones." Lithologically, these rocks are for the most part found to be altered diabases, with, exceptionally, augite-porphyrates also considerably altered. In regard to their state of aggregation, these volcanic materials represent all the usual products of eruptions, including effusive rocks, sometimes amygdaloidal, and tuffs. There is also, throughout the entire series, more or less evidence of subaqueous deposition and bedding, while no proof has so far been obtained in this district of the existence of sub-aërial accumulations.

The following summarized general sections, based on the more detailed descriptions given in the sequel, best represent what is known

General sections.

of the Nicola formation, in the eastern and western parts of its area respectively. The sections are in descending order.*

Thompson River, south of the Ashcroft Cretaceous area.	Feet.	Vicinity of Nicola Lake.	Feet.
Limestone (20' or more).....	20		
Fine grained felspathic rocks, sometimes well bedded, generally gray.....	1,800	Fine grained felspathic rocks, generally well bedded.....	1,200
Tuffs or ash rocks, passing into agglomerates, with some fine grained felsites, gray, purplish and green; a few small limestone beds near the base.....	7,840	Diabases, chiefly effusive and sometimes amygdaloidal; some tuffs; two thin beds of limestone near the base.....	3,700
Chiefly green diabase agglomerates, often coarse. Several calcareous beds and limestones. Dark felsites at base.	3,930	Chiefly green diabase agglomerates, occasionally amygdaloidal. Thickness at least 2,600 feet, and possibly 6,000 feet (say).....	2,600
Approximate total.....	13,590	Approximate total (minimum).....	7,500

In explanation of the above sections, it may be added that although placed in parallel columns, the equivalency of the several groups of beds is intended merely to be suggested in the most general way. If the maximum thickness be assigned to the lower group in the Nicola section, there would be a nearer approximation to correspondence in total thickness, but the rendering of this part of the section is doubtful. Further, it must be noted as possible that the amphibolites and argillites of the Douglas Lake vicinity, with a thickness of about 7000 feet, may eventually have to be added to the Nicola formation in that region. This question has already been alluded to on page 45 B.

Trias of Queen Charlotte and Vancouver islands.

Representatives elsewhere of the Nicola Formation.—In the year following that in which the Triassic age of these rocks was recognized in the inland region of British Columbia and the name Nicola series was proposed for them, Triassic rocks of essentially the same character were discovered in the coast region, in the Queen Charlotte Islands.* At a still later date, the formation last referred to, was found to be continued to the south-eastward, in the line of the same mountain axis, and to form the greater part of the older rocks of the northern portion of Vancouver Island.† Like the Nicola formation, the Vancouver formation, as it was then called, is chiefly composed of

* Report of Progress, Geol. Surv. Can., 1878-79, p. 45 B *et seq.*

† Annual Report, Geol. Surv. Can., vol. II. (N.S.), pp. 7 B-10 B.

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old volcanic products, described as follows in the report last cited:—
 "These rocks are now represented by hard amygdaloids and agglomerates of general dark greenish colours, though often grayish and sometimes purplish or reddish; by felsites, more or less porphyritic, and by hard regularly stratified ash beds, which, where the alteration has been most pronounced, are locally changed to hornblendic or micaceous schists."* With these volcanic products limestones and argillites holding characteristic Triassic fossils are interbedded.

In the Vancouver formation, or series, the limestones and argillites are somewhat more important than in the Nicola formation, but otherwise the resemblance between the two, both in regard to their original mode of production and their present appearance, practically amounts to identity. Notwithstanding this fact, it is believed to be appropriate to retain distinctive local names for the two great developments of Triassic rocks in British Columbia. In both cases the lower and upper limits of the formation remain more or less indefinite, chiefly because of the absence throughout great masses of the strata of any organic remains, and thus one may extend in its lower or upper beds through a part of the geological time-scale considerably greater than the other. It is moreover found to be a general rule in this part of the Cordillera, that exact equivalency of formations is scarcely to be sought for at any considerable distance across the prevalent north-west and south-east trend of the main orographic features, and in this case, the nearest recognized representatives of the two formations are separated by a gap of about 150 miles transverse to this direction.

Equivalency
of Nicola and
Vancouver.

It is unnecessary in the present connection, and in the as yet incomplete state of our knowledge of the Triassic rocks of the west, to enter into any extended comparison of the Nicola formation with other rocks believed to be of the same age. It may suffice to point out that characteristic Triassic fossils, like those of the Nicola and Vancouver formations, have now been found in a number of places very far to the north and north-west of these typical localities, as on the Stikine, Liard and Peace rivers and even in the Alaskan peninsula;† and that it is evident that in this northern region the Triassic sea extended eastward completely across the Cordilleran belt. To what extent volcanic materials are mingled with those of ordinary sedimentary origin in these northern localities, remains in most

Triassic of the
north.

* *Ibid.*, p. 8 B.

† See Annual Report, Geol. Surv. Can. vol. III. (N.S.), page 54 B; *Ibid.*, vol. IV., page 19 D; Report of Progress, Geol. Surv. Can., 1876-76, p. 97. Bull. Geol. Soc. Am., vol. V., p. 122.

Rocky Moun-
tain red beds.

cases still to be determined. It may further be noticed, that no rocks like those of the Nicola formation are found in that part of the Rocky Mountains proper which is situated in latitudes similar to those of the region here particularly described, but on the contrary, that about as far north as latitude $49^{\circ} 30'$, certain red beds, the deposits of an inland sea, are there believed to represent the Triassic period. Between the northern part of this inland sea and the extension of the ocean in which the Nicola and Vancouver formations were laid down, land, occupying approximately the position of the Selkirk Range, appears to have formed a barrier.*

Comparison
with southern
Triassic.

To the southward, in the corresponding portion of the Cordilleran belt of the western part of the United States, the nearest available term of comparison for the rocks here described is found in the Taylorville region of California, some 700 miles distant. It is not intended to suggest that the intervening portion of the Cordillera differs in its structure, but it has not yet been carefully examined or studied, and in regard to all formations older than the Cretaceous, it remains practically unknown. Such cursory observations as I have been able to make in travelling through this intermediate region, comprised in the states of Oregon and Washington, lead me to believe that rocks representative both of the Nicola and the Cache Creek formations of British Columbia will ultimately be found to extend without any important break to California.

The Taylor-
ville sections.

In the Taylorville region,† near the fortieth parallel, in northern California, the rocks have been examined in detail, stratigraphically and paleontologically, by Mr. J. S. Diller, Professor A. Hyatt and others. The results arrived at by the two gentlemen named are given in a summarized form in papers contained in the Bulletin of the Geological Society of America.‡ It is there shown that the Triassic rocks are unconformable on those of the Carboniferous, that these rocks as locally developed are all referable to the Upper Trias, later than those of the Aspen Mountains, Idaho, or of the Star Peak Range, Nevada, while they are supposed to be limited above by a second unconformity which separates them from beds containing Jurassic fossils.§ No unconformity corresponding to the last has been recognized in

* For a further discussion of this point see Trans. Royal Soc. Canada, vol. I., sect. IV., p. 143 *et seq.*

† An area about 12 miles in length by 6 miles in width.

‡ Vol. III., 1892, pp. 369-412.

§ *Ibid.*, pp. 378-379. See also vol. V., p. 399. The evidence of the Jura-Trias unconformity as given by Mr. Diller, does not appear to be entirely satisfactory for a region so much disturbed as that of Taylorville.

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British Columbia where, on the contrary, the fossils referred by Professor Hyatt to the Lower Jurassic, occur in beds which appear to be conformable with those of the Triassic and which are included with them in the Nicola formation of this report. A great orogenic movement, however, took place previous to the deposition of the lowest Cretaceous beds, which is probably equivalent to the important unconformity in California elsewhere referred to by Mr. Diller.* Nothing beyond the few fossils above referred to, of supposed Lower Jurassic age, has yet been found in British Columbia to bridge the gap between the Triassic and Cretaceous, for the beds on the Iltasyouco River (Lat. 50°, Long. 126°), at one time supposed to be Jurassic, have been united by Mr. Whiteaves with the Cretaceous.†

The most interesting circumstance met with in the comparison of the sections examined by Mr. Diller with those of the Nicola formation, is the considerable proportion in which materials of volcanic origin enter into the composition of both, and the evidence thus afforded of the widespread character of volcanic action at this time.‡

Volcanic materials.

It is, however, probable that the lower rocks of the Nicola formation are considerably older than any of those recognized in the Triassic of the Taylorville district, and that the formation as a whole may correspond more closely with the period represented by the Triassic rocks of the Fortieth parallel region to the east of the Sierra Nevada and between that range and the Wahsatch Mountains, as described by Clarence King.

The rocks of this system are there divided into upper and lower series, designated as the Star Peak and Koipato groups, respectively, with a total thickness of some 16,000 feet. These rocks generally rest upon an Archean foundation, but pass conformably upward into the Jurassic. They are to a great extent composed of materials of ordinary sedimentary origin, but the important development in them of materials described as "porphyroids" and in some cases as "chloritic schists," induced me long ago, in the light of the composition of the Nicola formation, to venture the suggestion that such rocks really represent contemporaneous volcanic materials, although in the Geology of the Fortieth Parallel their character is accounted for as the result of some peculiar metamorphism. This suggestion has not yet,

Nevada section.

* *Ibid.*, vol. IV., p. 221.

† Report of Progress, Geol. Surv. Can., 1876-77, p. 158. Geological Magazine, decade II., vol. VIII. (1881), p. 218. Whiteaves, Mesozoic Fossils, vol. I., part III., p. 258.

‡ Bull. Geol. Soc. Am., vol. III., p. 376, etc. See also J. E. Mills on an adjacent part of California, p. 426. The rocks described by him are shown by Mr. J. P. Smith to be Triassic. *Ibid.*, vol. V., p. 250.

so far as I am aware, been borne out by any later investigation of the rocks, but it appears to me to be, in connection with the facts now established in the Taylorville region, more than ever probable.*

Conditions of Metamorphism affecting the Older Volcanic Rocks.

Metamorphism of volcanic rocks.

In order to understand the different forms in which the volcanic rocks of the Nicola series now appear, it is necessary not only to refer them to the original materials which they may be supposed to represent, but also to examine into the causes of alteration which have since operated upon them. In such an examination, the metamorphism of the ordinary sedimentary materials and of the limestones, which constitute a relatively small part of the great Triassic series as here developed, may be passed over, as being well understood and presenting no features not easily recognized. It is in respect to the mass of rocks of volcanic origin, of which by far the greater part of the formation is built up, that questions surrounded with greater difficulty and doubt arise.

Amphibolites of Campbell Creek.

The fine-grained amphibolites, which in association with hard slaty or schistose argillites constitute an important feature in the Campbell Creek section and in the vicinity of the Douglas Lake granite mass, (pp. 122 B, 136 B) although assigned provisionally to the C  che Creek formation, may be mentioned in connection with the remarks here made on the Nicola volcanic rocks. This is appropriate by reason of their association in the field, and also because they seem to illustrate what may be merely another form of metamorphism to which such volcanic materials are subject. Microscopic examinations of some of these rocks made by Mr. Ferrier, lead him to believe that they have resulted from the dynamic metamorphism of basic igneous materials, which may have resembled the diabases common in the C  che Creek formation, or those which constitute the greater part of the Nicola formation. There are, however, other varieties, difficult of study under the microscope, but which in the field, evidently grade into hard black argillites and into grauwacke sandstones, and in which no evidence of a foliated structure as distinct from the bedding planes are found. It does not, therefore, appear probable that these dark-coloured, fine-grained rocks have revolted merely from the metamorphism of the ordinary diabase porphyric. When evidently subjected to dynamic metamorphism, these ordinary diabases are observed to produce green and gray, lustrous, chloritic and sericitic schists. Where

Their mode of origin.

* See Trans. Royal Soc. Can., vol. I. (1883), p. 145. Geology of the Fortieth Parallel, vol. I., pp. 268, 271-272, 275.

affected merely by the temperature consequent on contact with granitic masses, they are found to pass into gray rocks of gneissic appearance, but free from quartz.

It is in fact supposed, that these amphibolite schists may represent highly altered basic tuffs, which have been deposited in water with frequent admixture of ordinary clayey material, and that their appearance of bedding really depends upon their original arrangement as sediments rather than upon any subsequent foliation. In any case, they appear to constitute, in the Stump Lake and Upper Nicola region, a set of beds with recognizable and somewhat peculiar characters which are of classificatory importance from a stratigraphical standpoint.

It may, however, still be argued that these amphibolites have been produced from the ordinary diabases of the region by a combination of temperature (or contact) and pressure effects, differing from that of either of these factors acting separately. I am not prepared to deny that this may be the case, although some of the circumstances cited above are opposed to such a belief.

Reverting to the other forms of alteration which are met with in the region, a few words may now be said respecting the kind of change which is clearly referable to the proximity of extensive granitic masses and may be described as a contact phenomenon. This is not equally apparent in the case of all contacts of these old volcanic rocks with the granites, a circumstance for which the reason cannot be given with certainty, but which very possibly depends largely upon the angle which the intrusive mass makes with the present surface. For, upon the assumption that the effect in the matter of alteration is equal in the case of each contact, it is obvious that this effect would be apparent for a relatively small distance when the plane of contact is vertical to the actual surface, while it might extend very much further when this plane cuts the surface obliquely. But in addition to this, it must be noted that a much greater degree of heat, of hydrothermal action and of pressure may have attended some of the contacts than that found in the case of others.

Metamorphism near granite contacts.

In the southern and stratigraphically higher part of the section which has been referred to as the Campbell Creek section, what is believed to be the normal change attending a contact of the diabases of the Nicola formation with granite is very well exemplified. The nature of this alteration is explained in some detail elsewhere (p. 123 B). It may suffice here to say that the green colour due to the general

Changes observed near contact.

alteration originally suffered by the diabases, and resulting from a change of a part of the augitic constituents into chloritic minerals which have become diffused through the mass of rock, has in this place and in others similarly situated, been eliminated. The ferruginous and basic constituents of the magma have rearranged themselves into black or dark-coloured new crystals of hornblende, while the felspathic constituents have recrystallized in colourless forms. The general tint of the rock thus changes from green to gray, and when nearly in contact with the granite it assumes a gneissic structure, though free or almost free from quartz. Mica is also very frequently developed along the planes of bedding or foliation, but this appears to result chiefly from the effect of pressure superinduced on that of the metamorphism due to mere increase of temperature.

Various granite contacts.

Along the zone of contact of the diabase series with the granites on the line of Moore Creek (p. 129 B) pressure appears to have played a considerable part in the aggregate change of the rocks. The neighbouring parts of the granite are often foliated, and gray micaceous-looking schists are frequent, though many of them when carefully examined are found to have the characters of amphibolites or epidiorites in so far as the bulk of their constituents is concerned. The same phenomena are repeated near the head of Clapperton Creek (p. 143 B), in some places on Guichon Creek (p. 144 B) and to the west of Jacko Lake (p. 138 B).

Dynamic metamorphism.

When, at any considerable distance from the granitic masses, the altered diabases have been subjected to great pressure alone, they tend to pass, as already noted, into the green and gray chloritic or sericitic schists, which are often lustrous and sometimes contorted and wavy in their planes of foliation. All intermediate stages between such rocks and massive and distinctly porphyritic diabases may be found in different parts of this field, and along the southern side of Nicola Lake (where this particular kind of alteration was chiefly noted as affecting the Triassic rocks) it is observed to be best marked in the vicinity of the compressed anticlinal axes. It is there also observed that the rocks so affected are usually highly calcareous, and it is possible that materials originally containing a considerable proportion of lime have passed most easily into such glossy schists.

It may here be remarked that, in the case of such schists within the area of the Kamloops sheet, no criteria have been found which, apart from stratigraphical evidence, suffice to determine their age. Under like conditions, rocks of originally similar character whether Triassic, Carboniferous or Cambrian in age, have been changed into

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green and gray schists in themselves indistinguishable. Neither is it possible in hand specimens, to make any distinction between the greenstones or altered diabases of these several and widely separated geological horizons.

Respecting the original character of the materials of the Nicola formation, now found in the various stages and kinds of alteration above referred to, it may confidently be stated that they have appeared as volcanic rocks not necessarily different from those which now reach the surface in regions of vulcanism. The great bodies of volcanic materials which at recurrent intervals appear to characterize so many different stages in the entire geological history of this part of the Cordillera, in themselves afford a practical clue to every step in the alteration of such deposits. The greenstones, or green altered uralitic diabases, now so abundant in strata of Triassic age and older, have undoubtedly at one time reached the surface as dolerites or as basalts, which in some cases have been effusive, in others of the character of volcanic breccias, or the finer forms of volcanic ashes or tuffs. Such deposits, whether thrown down sub-aërially and afterwards covered by later strata, or scattered and spread abroad in the waters of the sea of the period, are essentially the same. Under the last-named conditions, they are often well stratified, but unless subjected for prolonged periods to the leaching action of water, or intermixed with considerable proportions of calcareous or ordinary earthy deposits (both conditions which can only have prevailed when the rate of supply of the volcanic material was slow) they are the same in composition and remain subject to a similar series of changes.

Original character of Nicola rocks.

In the Tertiary volcanic rocks which cover so large a part of the same area, we find without difficulty the little changed or practically unaltered representatives of all the older volcanic rocks. The massive basalts, dolerites, melaphyries and augite-porphyrates, with agglomerates composed of those rocks, afford the materials which, by a breaking down of their original constituents and some concurrent recrystallization of them, lead to the production of diabases. By a further change, affecting principally the augite of the diabase and resulting in its conversion into hornblende, wholly or in part, the characteristic "greenstone" or altered diabase of the region may be formed, of which the still further changes have already been traced. In a similar manner, the bedded tuffaceous rocks of the Tertiary evidently represent the clastic materials of many of the older rocks. The acidic volcanic rocks need not be considered here in detail, for though rocks of this character are present in the Tertiary accumulations, they have not so

Analogy with Tertiary volcanic rocks.

far been recognized as playing any important part among the older rocks of this particular region.

Cretaceous.

Eastern limit
of Cretaceous.

Strata referable to the Cretaceous period, occur in the western half of the Kamloops sheet alone, and there only as insets among the older rocks due to folding, or folding and faulting combined. These rocks have not been recognized to the east of the Ashcroft Cretaceous area, and a more general survey of the conditions in British Columbia renders it probable that the Cretaceous sea at no time extended much further east in this latitude. The deposits consist largely of coarse clastic materials, including massive conglomerates, which in all probability indicate a sinking shore-line. But it is further evident that we can now possess but residual fragments of a formation which must at one time have been much more extensive, for the conditions imply that at the time of the deposition of these beds the Coast Ranges were either non-existent, or that they were broken and discontinuous, so that the Pacific Ocean of the period obtained free access nearly to the centre of the region which now forms the Interior Plateau of British Columbia.

Areas in map-
sheet.

The residual Cretaceous areas of the Kamloops sheet, which have escaped the great post-Cretaceous denudation, may be designated as the Fraser River area, the Ashcroft area and the Botanie Creek area respectively; the last-mentioned being quite inconsiderable in dimensions.

Composition
of the rocks.

The excessively crushed and disturbed condition of all these Cretaceous rocks, has so far rendered it impossible to obtain any complete general section of them; but it would appear that in the Fraser River area, hard black argillites and black fine-grained sandstones or quartzites form the lower part of the series, while gray and green-gray sandstones, with massive conglomerates, prevail in its upper part. In the Ashcroft area, on the other hand, the lower part of the formation seems to consist chiefly of green or green-gray sandstones or quartzites, while dark, shaly, and fine-grained sandstones are more abundant in its upper parts, conglomerates being less important at all stages. In the Ashcroft area there are, however, some coarse sub-angular grits and conglomerates towards or at the base which appear, to represent true "basal conglomerates." These, in one place (about two miles south-east of Black Cañon), are represented by a bouldery conglomerate, passing below in a few feet into an angular breccia, which rests unconformably upon the Nicola rocks. The conglomerate

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and breccia are here almost entirely composed of granitic material of proximately local origin, with a calcareous and arkose paste.

The Ashcroft area lies some twenty miles to the east of the Fraser River area, and it is quite possible that its lower, coarse, clastic beds, may represent the littoral equivalents of a portion of the lower beds of the Fraser River, while the conditions for the deposition of finer beds may have extended to both areas at a later stage with an increasing depth of submergence. In this case, it may be conjectured that the higher portions of the series as represented along the Fraser, are now not found in the portion of the formation preserved in the Ashcroft basin. It must, however, be explained, that in both areas no definite line of division exists between the different classes of rocks, sandstones, conglomerates and argillites occurring more or less indifferently at all stages.

The thickness of the entire series in the Fraser River area, is estimated to be about 7000 feet, while in the Ashcroft area about 5000 feet of beds appear to be represented, and it is not improbable that if a complete section could be reconstructed, the Cretaceous rocks would be found to possess in the aggregate a volume approaching 10,000 feet.

The greenish and green-gray hard sandstones or quartzites which form so large a part of this formation, are so peculiar in character as to deserve a word of special mention. On microscopic examination some of these rocks appear to be chiefly composed of granitic debris, and may therefore be termed arkose rocks or sandstones, while others have all the characters of diabase tuffs.* But the occurrence of true tuffs implies the existence of volcanic eruptions contemporaneous with their deposit, of which there is no definite proof within the limits of the region here under consideration. The underlying and adjacent Triassic and Paleozoic rocks, however, abound in diabases and such-like materials of volcanic origin, and it is probable that the rocks here spoken of are in many cases reconstructed or secondary tuffs or grau-wackes composed of such materials, when these instead of the granitic rocks have constituted the source of supply of debris going toward the formation of the Cretaceous sediments. The composition of the conglomerates, with that of beds intermediate in coarseness of constituents between these and the hard greenish sandstones, go far to support this view. It must, however, be added that, in other parts of the Cordillera, the products of contemporaneous volcanic eruptions have

Character of
sandstones
and conglomerates.

*See Appendix I., Nos. 38, 39, 40.

entered largely into the composition of the Cretaceous beds and particularly into those of the Earlier Cretaceous.*

Geological position.

Respecting the precise geological age of these rocks, it may here be sufficient to state that they are, for the most part, the local representatives of a great Earlier Cretaceous series which is very widely spread in British Columbia, and of which the fossils from a number of localities have now been studied in detail by Mr. J. F. Whiteaves. To this, the name Queen Charlotte Islands formation has been applied as a general one, as from these islands the greatest body of paleontological evidence, with the best general section of the rocks, has been derived.

For further details on the equivalency of this with other recognized Cretaceous areas, earlier publications by the writer and Mr. Whiteaves may be consulted.†

Fossils obtained.

Within the area of the Kamloops sheet, the whole number of Cretaceous fossils so far found is very small. In addition to the few plants elsewhere mentioned, only two species of molluscs have actually been determined. These are *Aucella Mosquensis* var. *concentrica* and *Pecten (Syncyclonema) Meekiana*. No fossils have yet been obtained from the Ashcroft area.

Beyond the edge of the present map, however, the Cretaceous rocks run along the Fraser valley for many miles to the southward, the trough terminating in a mountainous country to the east of Boston Bar and North Bend.‡ This southern extension of these rocks was examined by Dr. Selwyn in 1871, and the rocks were then provisionally referred to by him as the "Jackass Mountain Group," though their age was unknown.§ Subsequently (in 1875) these rocks were, on lithological grounds, correlated by the writer with those of Tatlayoko Lake (of which the age had been fixed by fossils)||; but in 1877 they were found to yield some fossils in Dr. Selwyn's original locality, and these bore out the reference just alluded to. The fossils obtained at that time, which may be taken as equally characteristic of the rocks of the Fraser River area within the present sheet, are *Belemnites impressus*, Gabb, *Pecten (Syncyclonema) Meekiana*, Wh., *Ancyloceras percostatum*, Gabb.

* Reports of Progress, Geol. Surv. Can., 1876-77, p. 58; 1878-79, p. 69 B; Annual Report, Geol. Surv. Can. vol. I. (N.S.), p. 164 B.

† See especially Am. Journ. Sci., vol. XXXVIII., p. 120; Trans. Royal Soc. Can., 1893, sect. IV., p. 3.

‡ Report of Progress, Geol. Surv. Can., 1877-78, p. 107 B.

§ Report of Progress, Geol. Surv. Can., 1871-73, p. 60.

|| Report of Progress, 1875-76, p. 253.

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Crioceras latus, Gabb, *Pholadomya Vancouverensis*, Wh., an *Arca* like *A. Carteroni*, D'Orb., and a *Cucullaea*.*

The small collection of fossil plants which is reported on by Sir J. Wm. Dawson on a following page (p 148 B), goes to show that beds as late as the Dakota period must occur in the Fraser River area, and this is quite in accord with the general views previously enunciated of the limits of the Earlier Cretaceous series of British Columbia.†

We have here in fact beds equivalent to those of the Queen Charlotte Islands formation (including the three lower subdivisions of the general section in these islands‡) together with higher beds, which like the conglomerates of the Queen Charlotte Islands (subdivision B) and other conglomerates found on the Lewes River and in the Kootanie district, represent the Dakota period with possibly some part of the Benton period, of the province of the Great Plains. Further, these Earlier Cretaceous rocks correspond in a general way to the group long known in California as the Shasta group. The molluscs above enumerated appear to be essentially those of the Knoxville or lower division of that group.

It has been found impossible to determine any of the fossils in a small collection obtained on Stein Creek, but these appear to be freshwater forms. Whether they represent a stage during which the sea was actually excluded from a part of the region, is not known, nor can the stratigraphical relation of the particular beds in which they occur to the others be stated. It is of course quite possible that these beds, or others which may yet be discovered, may be found to be related to parts of the Cretaceous even higher than the Dakota horizon. The late determination, by Messrs. Diller and Stanton in California,§ of the fact that the Shasta and Chico form parts of a practically unbroken series there, tends to indicate that similar conditions may prevail here also, but no fossils characteristic of the Chico period have so far been found on the mainland of British Columbia.

In concluding these general remarks on the Cretaceous, something should be said on the possible relation to it of the conglomerates elsewhere referred to the Coldwater group and described as probably Oligocene (pp. 68 B, 76 B). The question has several times occurred, whether these conglomerates may not actually represent local developments of

Relations of
Cretaceous
and Cold-
water con-
glomerates

* Report of Progress, Geol. Surv. Can., 1877-78 pp. 108 B, 109 B.

† Am. Journ. Sci., vol. XXXVIII., p. 125.

‡ Trans. Royal Soc. Can., 1893, sect. IV., p. 15.

§ Bull. Geol. Soc. Am., vol. V., p. 435.

parts of the Cretaceous series elsewhere represented in the region, or an upper member of that series. This suggestion cannot be quite definitely negatived, but I believe the evidence to be almost conclusive against it. In its favour, the very high angles at which the conglomerates in question are often found, and the occasional occurrence in them—particularly as basal beds—of conglomerates lithologically closely resembling those of the Cretaceous, may be cited.

On the other hand, we find them in aspect and composition generally, to differ much from the Cretaceous conglomerates, while the associated sandstones are also very different in the two cases. Still more conclusive, however, is their apparently definite association with undoubted Tertiary lignite—and coal-bearing rocks at Hat Creek and on the Nicola. The fact that these conglomerates occur on Hat Creek in a position geographically intermediate between the Ashcroft and Fraser River Cretaceous areas, while quite unlike the rocks of either, and unaffected by the severe compression which has affected both of these areas, is also significant. It remains, however, still possible, that isolated areas of conglomerates due to the Cretaceous period may have been confounded with the Coldwater conglomerates proper in some cases.

Economic
features.

The Cretaceous formation as represented in this region is not entirely without economic interest. The evidence of the fossils shows that it represents a stage of the Cretaceous at which in the Queen Charlotte Islands on one hand and in the Kootanie region of the Rocky Mountains on the other, important coal-beds were in process of deposition. No coals have yet been found in these particular rocks, but the occurrence of carbonaceous shales and of plant remains, serve to show that a slight change in the conditions in some part of the extent of the formation might have led to the production of coal, which may in that case yet be discovered.

Again, the massive conglomerates of the Cretaceous have possibly had something to do with the supply of gold in adjacent parts of the Fraser Valley, for these conglomerates, representing as they do an extensive Cretaceous erosion, may well have become in certain layers charged with gold derived from the older rocks, which may subsequently have found its way, in the course of later erosions, into the bed of the present river. This subject is, however, returned to in the sequel.

Tertiary.

Earlier observations.

In my preliminary report on the southern portion of the interior of British Columbia,* the Tertiary strata were treated of as a whole and

*Report of Progress, Geol. Surv. Can., 1877-78.

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no attempt was made to establish subdivisions among these strata. The following statement on this subject was, however, made:—"It is by no means improbable, that the Tertiary rocks of this part of British Columbia may eventually admit of separation into several distinct series representing different stages in the Cainozoic period, but palaeontological evidence of this is yet wanting." (p. 112 B).

The much more detailed examination of that part of the same region now included in the Kamloops sheet, still fails to afford the necessary palaeontological data for any complete subdivision of the Tertiary rocks. So great a part of these rocks is moreover of volcanic origin, that it is perhaps too much to expect the discovery of sufficient evidence of this kind from the relatively insignificant sedimentary beds. It has, however, become very clearly apparent that the rocks here collectively referred to as Tertiary, represent a very long period of time, with several changes of condition, and that there are also probably one or more gaps, unrepresented so far as known by deposits of any kind. These general facts are established chiefly by the stratigraphical and other physical characteristics and relations of the rocks, but they are borne out also in a measure by the slight evidence to be obtained from fossils. These consist almost exclusively of plant and insect remains, obtained from several localities, of which one of the most striking peculiarities is the diversity of each collection from the others. On this particular subject, a few more detailed notes are given in the sequel.

Several members in the Tertiary.

The impossibility of defining separate formations of the Tertiary, even for the area of the Kamloops sheet, thus still renders it appropriate to speak of these rocks in the aggregate, as they are met with in each particular natural district. An attempt to follow a systematic order of treatment, would involve an undue reliance on hypotheses which subsequent investigation may prove to be more or less unsound. A general sketch of the composition and relations of the Tertiary strata as a whole, will therefore first be given, in this part of the Report, together with such facts or theories as have been reached or are tentatively held on the equivalency and correlation of horizons. Each naturally defined area will then, in a subsequent part of the Report, be separately described, taking first and in greatest detail those in which the more complete and instructive sections have been found. Briefer mention will in the last place be made of the Tertiary rocks of the other parts of the region. This method of treatment does not admit of a strictly geographical order of description, but if followed with the aid of the map, will, it is believed, give the best picture of the whole.

Method of treatment in Report.

Degree of accuracy in delineation.

To avoid possible misconception, it must further be stated that the Tertiary rocks were originally examined in the field as an aggregate, and that it became apparent only in the course of this work that they might be usefully subdivided into the several groups now adopted. Thus, while the outlines of the Tertiary as a whole are believed to be shown on the map with such accuracy as its scale and the nature of the surveys admit, the separation of the volcanic materials of the formation into upper and lower parts is of a much inferior order of precision. It indeed became a question in the compilation of the map, whether any attempt to outline the several areas of these two members of the Tertiary should be made, but it was eventually decided that it would be best to indicate these as nearly as possible, with the proviso that such indication must be regarded as a first rough sketch only of the facts.

Coldwater group.

Before the beginning of the period of Tertiary vulcanism in this region, certain beds had been deposited which consist entirely of ordinary clastic materials. These beds were laid down in lakes or river-estuaries, in hollows then existing in the old denuded surface of the Paleozoic and Triassic rocks. They consist chiefly of conglomerates, sandstones and shales, with which coals and lignites are in some places associated. These particular beds have not been found in actual unconformity with the upturned Cretaceous rocks of the Thompson or Fraser, but as they do not appear to have participated in the great crumpling of the Cretaceous, which probably took place at or about the close of the Laramie period, they are regarded as post-Cretaceous and probably as post-Laramie.* They may therefore be described as intervening between the close of the Cretaceous and the inception of the great volcanic period in this region.

Its character. The nature of the deposits, and particularly the abundance of well-worn conglomeritic material in them, seems to show that they may very well represent the work of some river systems of the great early Tertiary time of denudation, during which the Interior Plateau was being worn down to an approximately level surface. Particularly on the interruption or close of this period, might such deposits be formed.† But as the time involved was undoubtedly very long, the isolated deposits now found in various parts of the field might very well be referable to horizons differing widely, although all included in the early part of the Tertiary.

* See however p. 65 B.

† In my paper on the Physiographical Geology of the Rocky Mountain Region, already referred to, these deposits are not separated from those classed as Miocene. The facts here stated show that they probably belong to an earlier period, most likely to some part of that described on p. 11 of the paper above referred to.

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It is found, however, that there exists, in several separate localities, so complete a lithological resemblance and similarity in the order of superposition of these deposits, that there can be little, if any doubt that the beds of these localities are contemporaneous and due to the same sequence of events in the Tertiary history. The deposits thus evidently related are those of the following places:—Hat Creek valley, Copper Creek, vicinity of the confluence of the Coldwater and Nicola, and, (to the south of the Kamloops sheet) near Lac à la Fourche. In each of these places the lowest beds are found to consist of conglomerates almost entirely composed of materials of proximately local origin, followed by conglomerates largely composed of well-rounded cherty pebbles, with which some sandstones are associated. Above these, in the Coldwater-Nicola vicinity and on Hat Creek are sandstones and shales with coals and lignites.

Identity of several developments.

It is proposed to designate these evidently synchronous deposits by the name of the *Coldwater group*, and there can be little doubt that the conglomerates found on the plateau to the west and south of Savona, as well as these forming small outliers on the Garde Lafferty, represent further remnants of the basal conglomerates of the same series. In the case of the sedimentary deposits of the North Thompson, situated near the north edge of the map, no distinct lithological identity can be appealed to, but there is at least nothing to show that they differ in age from those of the Coldwater group.

The Coldwater group as a whole, evidently represents the remnants of a once more extensive formation, most of which has been removed by denudation, and of which what still exists is often covered by the later volcanic materials. It may in part be regarded as filling hollows in the pre-existing surface, but this surface has since been considerably modified in its relief by later flexures and by some faulting, and it is thus generally in synclinal folds, or where let down by faults, that the Coldwater beds are actually found. It is, therefore, impossible now to determine whether the remaining beds of the series represent portions of a deposit once largely spread over the area of the Kamloops sheet, or, if more restricted, what areas such deposits may originally have covered.

Original extent uncertain.

That these deposits antedate the period at which volcanic activity on a great scale began, is rendered evident by two circumstances. They include in their material no characteristic volcanic Tertiary rocks while they appear without doubt to be affected by more pronounced folding than that affecting the volcanic rocks.

Older than volcanic Tertiary

In some places these beds are now nearly or quite vertical. This is particularly the case near Clapperton and Copper creeks; but in other

Attitude of the strata.

localities, as for instance on the plateau to the west and south of Savona, the basal conglomerates are found to be still nearly horizontal, or inclined at comparatively low angles like those normal in the case of the later volcanic rocks of the Tertiary. In the place last mentioned, not only are the basal conglomerates nearly flat, but they differ but a few hundred feet in elevation from their similarly undisturbed representatives in outliers on the Garde Lafferty—twenty miles distant. Thus it would appear, that after the Coldwater beds had been laid down, a period of orogenic movement occurred, by which these beds were affected particularly along certain lines, running in north-north-west by south-south-east bearings, while large intervening blocks of country preserved their rigidity; that a period of denudation followed, during which a great part of the Coldwater beds was removed, and that the denudation had been long in progress before the first beds of the succeeding volcanic series were formed.

Relation to
Nicola rocks.

In connection with the relations of the Coldwater beds, it may further be noted that, though unconformable on the rocks of the Nicola formation, they are found near Clapperton Creek, and south of Lac à la Fourche to rest on certain purplish porphyrite rocks which are believed to occupy a position not far from the summit of that formation, a fact showing that the beds of the Nicola formation may not in some places have suffered very extreme disturbance before the time at which the deposition of the Coldwater beds began.

Character of
conglomer-
ates.

It has already been noticed that the basal beds of the Coldwater group, consisting chiefly of conglomerates and breccia-conglomerates, but with some grauwacke and arkose sandstones, have derived their materials largely from the immediately underlying surface. The conditions are such as to imply a somewhat rapid working over of that surface by the gaining waters of the lake or lakes in which the Coldwater beds were formed. Above these, and by a gradual passage, the conglomerates become charged with well-rounded pebbles, preponderately of cherty materials, and these conglomerates are perhaps the most characteristic lithological feature of the series, having a great thickness, particularly on the lower part of Hat Creek and on Copper Creek. The cherty pebbles have evidently been derived from the Cache Creek beds, referred to the Carboniferous period, which are found to have their greatest development in a zone of country running southward from Clinton, in the vicinity of the Bonaparte and Thompson valleys, to latitude $50^{\circ} 30'$. Still further to the south, this zone appears now to be entirely covered by the later volcanic rocks of the Tertiary, but its occurrence in that part of the region may

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be argued from the composition of the conglomerates near Clapperton Creek and Lac à la Fourche. It is further apparent, that the rocks of this zone must, at the time of the formation of these conglomerates, have occupied a position more prominent than they now do with respect to the general relief of the surface; while the appearance of so great a proportion of the cherty material in the conglomerates, where these are now found at some distance from the beds yielding this material, indicates the existence of rapid streams, actively engaged in the erosion of the strata of the cherty zone and capable of carrying their débris away with ease. The volcanic rocks of the Nicola formation, of which the main development lies to the eastward of the line occupied by these conglomerates, although they had contributed so largely to the Cretaceous rocks, were not at this time supplying much material to the conglomerates, nor are the limestones of the region west of the Thompson often represented.

All this argues considerable orographic change both before and since the time of origin of the conglomerates, while the later Tertiary rocks are evidently in their physical relations much more nearly in accord with the conditions of surface still obtaining in the region. In other words, there is every reason to believe that an unconformity due to orogenic movement along certain lines, followed by a period of erosion, separates the Coldwater beds from all the later representatives of the Tertiary. Local deposits due to this period of crustal movement may exist in some parts of the region, but if so they have not yet been clearly recognized as such, although tuffaceous sandstones are not infrequent at the apparent base of the overlying volcanic series.

Orogenic
change closing
Coldwater
epoch.

After the events above noted, the great period of Tertiary vulcanism began. The principal volcanic centres within the area of the Kamloops sheet, were evidently situated along the line formed by the Clear Mountains, Mount Murray and Arthur's Seat. Here the volcanic action was probably initiated. The high mountains above designated represent the greatest mass of volcanic materials in the district, and many circumstances discovered during the investigation of the geology of the region, go to show that the main vents (during at least the whole of the earlier stages of vulcanism) were situated along this line, parallel in direction to that of the Coast Ranges, but separated from these ranges and lying a little to the east of them. Further to the south-eastward, although no prominent mountains of the same kind are found in the vicinity of the Nicola, the great thickness of the lower volcanic members of the Tertiary there, indicates the continuation of the same line of eruption and probably that of local subordinate vents. There

Early Mio-
cene volcanoes

were also no doubt other lesser foci of eruption at the same time in different parts of the Interior Plateau region.

Products of
their eruption.

The rocks of which the Clear Mountains are principally composed, may be described as consisting of hard, gray, greenish and purplish augite-porphyrates with occasional examples of diabase-porphyrates. These comprise both effusive and fragmental materials. Other rocks met with in these mountains or in their vicinity are noted in connection with the more detailed descriptions given in a later chapter.

In the vicinity of the Nicola Valley, the products of the earlier eruptions are represented by very similar porphyrites and porphyrite-agglomerates, passing into tuffaceous agglomerates and including many other varieties of volcanic materials in lesser quantity; the aggregate thickness being about 5300 feet.

Persistence of
volcanic
action.

One of the detached minor vents which appears to have been active to some extent during this earlier period of vulcanism, is that of Kamloops Lake, where the most abundant material discharged at about this time has taken the form of a dolerite. It is likely, however, from the close connection of this rock with the succeeding Tranquille beds, that it was poured forth only toward the end of the earlier period of activity. From the beginning of the Tertiary eruptions till their close, though the eruptions were doubtless more or less irregular and spasmodic, the accumulation of materials of volcanic origin in the plateau region probably never entirely ceased. The occurrence of water-bedded rocks, composed almost altogether of rearranged volcanic debris, indicates the formation of lakes which endured for considerable lengths of time, and the blocking up of the old drainage channels of the country by the lava-flows or other volcanic products, may to a great degree if not entirely, explain the impounding of these waters.

Tranquille
beds.

There was, however, apparently, one such very notable interlude, of which the water-arranged deposits are believed to be recognizable over a wide area. To the deposits then formed, the name of *Tranquille beds* has been applied. They are largely developed in the vicinity of Kamloops Lake, particularly near the mouth of the Tranquille River, and the persistent zone of stratified tuffs met with on the Nicola River, is believed to pertain to the same horizon. Volcanic action was not entirely quiescent during the formation of these beds, for they include much material which appears to represent volcanic ash, while they are often found to graduate almost insensibly into tuffaceous agglomerates. That the time represented by these deposits was

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of some duration, is shown by the fact that they include thin beds of coal near Kamloops. Other localities in which beds supposed to be referable to this horizon are found, are mentioned in the succeeding descriptive portion of the report.

To this important lacustrine episode, succeeded a second great period of volcanic action, of which the products are in the main basalts and basalt-breccias, with smaller quantities of melaphyre, micatrachite, mica-andesite, etc., and some porphyrites and other rocks resembling those of the first period. The old volcanic foci of the Clear Mountains have suffered so greatly from subsequent erosion, that it is not possible to decide to what extent they may have supplied the material of these later eruptions, though basaltic flows are still found patched upon their slopes at considerable elevations and sometimes lying at inclinations which appear to descend from their axis. It is in fact probable that much of the basaltic material was ejected from minor and less regularly aligned vents or fissures, scattered over various parts of the Interior Plateau. The Kamloops Lake vent, of which Battle and Cherry bluffs represent basal remnants, was evidently one of the more important local sources of the basalts. This is indicated by the thickness of the basaltic agglomerates in its vicinity, the large size of their component fragments, and the quaquaversal dips still found to characterize them. Similar circumstances, though less pronounced than in this case, indicate that Porcupine Ridge, as well as one or more places in the Arrowstone Hills were also centres of basaltic eruption, while there were probably many lesser sources.

Second volcanic period.

Centres of eruption.

There is no evidence such as to show that any prolonged period of rest occurred in the course of these later eruptions. Neither is there any direct evidence of orogenic movement between the first period and the second period of great volcanic activity; for although it is true that the older volcanic products are now more frequently found resting at comparatively high angles of inclination, this may in part be due to the original slopes upon which they were deposited, in part to the fact that in consequence of much later erosion, they now often occupy the peripheral portions of the volcanic areas, where they are in contact with the old rocks, and where whatever flexure has occurred is always found to be greatest. In any case, much the greater part of the area now occupied by the basalts is characteristically flat and undisturbed, or inclined at slopes so light that it is very difficult to tell to what extent these may be original and to what extent superinduced.

Relations of deposits.

The thickness of the upper, or preponderantly basaltic part of the Tertiary, in the vicinity of Kamloops Lake is about 3000 feet. In

Thickness.

the Nicomacien Plateau about 3100 feet ; but in many other places and over great areas of the map, these rocks form a comparatively thin and uniform covering of the surface of the plateau, consisting of wide-spread flows, with which little agglomerate is associated.

Changes in
the Pliocene.

When this second epoch of great volcanic activity ended, the great later Tertiary period of denudation and erosion began. The Interior Plateau ceased to be an area of deposition and became one of waste. It is, nevertheless, probable that the volcanic forces died out slowly, for some subordinate basaltic flows appear to have occurred after certain valleys had again been cut out to a considerable depth. Possibly some of these later flows may be more correctly referable to the Pliocene, but no sufficient evidence of this has yet been found in the southern part of British Columbia.

Pliocene de-
posits.

Some fragments of evidence have been found in the area of the Kamloops sheet, such as to show that about the time of cessation of the main period of basaltic eruption, or perhaps at a somewhat later date, but antecedent to the glacial period, lakes were again formed over certain parts of the surface, and that in these a certain amount of sedimentation occurred. These lakes were, however, doubtless small, and as compared with those of earlier dates, transitory ; for it is probable that before the great erosion of the latest stages of the Tertiary advanced far, the surface became supplied with a completely developed drainage system.

On the upper part of Hat Creek, where conglomerates chiefly composed of basalt pebbles occur, and again on the south-west slope of Pavilion Mountain, the deposits of such newer lakes are believed to be represented. In fact, the contour of the country and the elevation of these deposits at the two places, is such as to show that they may be attributable to a single lake, though some twenty miles apart.

If the later covering of drift deposits could be stripped from the surface, it is very probable that more beds of the kind just mentioned would be found in some of the valleys, but the instances cited are the only ones so far met with. On the assumption that the main period of vulcanism closed about the end of the Miocene, such later lake-basins must be referred to the early Pliocene ; but the history of the Pliocene or latest period of the Tertiary is written almost exclusively in erosion. It was a time of waste, in which the land stood high, and during which nearly all the existing river-valleys of the Interior Plateau were carved out.

Pliocene de-
nudation.

Probably many remnants of deposits due to this period of denudation, and of the nature of river-gravels left behind on terraces or in

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sheltered nooks of the larger valleys still remain, but they must be, as a rule, now entirely concealed by the later glacial deposits, from which it would moreover be difficult to separate them in many cases. But a single apparently definite instance of such deposits has been met with in the area here treated of. This is a small patch of coarse river-gravel, now hardened into a conglomerate, which remains on the east side of the Fraser Valley near the mouth of Fourteen-mile Creek. Since the time of its deposition, the river has cut down its valley by about 1000 feet.

Attention has so far been directed merely to the composition and relative order of the members of the Tertiary system within the area of the Kamloops sheet. A few words may now be added with reference to what little is known of their actual age and the positions they may be assumed to hold in the geological scale.

Probable age
of Tertiary.

Nearly the whole of the fossils which have been collected from the Tertiary of various parts of the interior of British Columbia are the remains either of plants or of insects. The greater number of such fossils so far obtained from any part of the southern portion of the interior, are derived from localities in the Similkameen Valley, near the confluence of the Tulameen. These localities are parts of a single Tertiary basin which has not yet been traced into connection with any other, and which may have been originally a distinct lake. It lies nearly fifty miles beyond the southern edge of the Kamloops sheet, and is now included in the drainage basin of the Columbia River.

Fossils.

What has been said with regard to the existence of two well marked horizons of stratified deposits within the area of the Kamloops sheet, and in respect to the causes to which these are due, appears to render it probable that the Similkameen beds may correspond in time with one or other of these horizons, and their appearance and mode of occurrence accords best with the hypothesis that of these two they represent the lower or Coldwater horizon, but for the present this correlation stands merely as a probable conjecture.

Comparison
with Similka-
meen beds.

In a review of the Tertiary flora of the region, which has been described by him, Sir J. Wm. Dawson finds reason to believe that the Similkameen plants are referable to the Lower Miocene or to the Oligocene.* Of nineteen species of hemipterous insects found in the Tertiaries of British Columbia, sixteen come from the Similkameen localities, and although all the species but one are new, their general facies is, according to Dr. S. H. Scudder, rather indicative of an Oligocene age,

Oligocene
fossils.

* Trans. Royal Soc. Can., vol. VIII., sect. IV., p. 90.

although some elements of the fauna show relations to that of Radoh, which is regarded as Middle Miocene.* Lastly, among a few poorly preserved remains of fishes which have been submitted to Prof. E. D. Cope, one from the Similkameen has been recognized as an *Amyzon*, and is regarded by him as showing the equivalency of the beds with the "Amyzon beds" of Oregon.† The age of the Amyzon beds Prof. Cope supposes to be Oligocene, although again in this case with some doubt.

In the Coldwater beds, at the mouth of the river of the same name, a few insects have been found, but these are all Coleoptera and all distinct from Similkameen species, while they are insufficient in themselves to afford any criterion of age.

General
Tertiary
sequence.

As a result of the determinations above referred to, it may, I think, be fairly concluded that the Similkameen beds are probably of Oligocene (later Eocene) age, and there is a good deal to be said in favour of the belief that the Coldwater beds and their equivalents in different parts of the Kamloops sheet hold the same position. In this case, the probable unconformity between the Coldwater group and the earliest of the overlying volcanic deposits, would mark the close of the Eocene for the region, while the great volcanic accumulations, with the Tranquille intercalation, and perhaps some other similar intercalations, would represent the Miocene period as a whole. Above these come the scanty traces of Pliocene sedimentation already referred to.

A provisional scheme of the Tertiary rocks met with in the Kamloops sheet may therefore be drawn up as follows:—

	Feet.
Tertiary deposits. <i>Early Pliocene</i> —	
Beds of Upper Hat Creek and N. part of Pavilion Mountain.....	—
<i>Later Miocene</i> —	
Upper part of great volcanic series.—Widely spread over the region.	
Greatest thickness, between Nicomen and Nicola (about)....	3,100
Tranquille group.—Chiefly volcanic materials arranged in water.	
Tranquille, Nicola valley, etc. Greatest thickness (about).....	1,000
<i>Earlier Miocene</i>	
Lower part of the great volcanic series.—Nicola valley, Clear Mountains, Kamloops Lake, etc. Greatest thickness, apart from centres of eruption (about).....	5,300
<i>Oligocene</i>	
Coldwater group.—Near confluence of Coldwater and Nicola, Copper Creek, Hat Creek, etc. Greatest thickness on Hat Creek (about),	—
Total.....	14,400

* Contributions to Canadian Paleontology, vol. VI., p. 6.

† Proc. Acad. Nat. Sci. Philadelphia, 1893, p. 401.

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* Annu

Plutonic Rocks.

The plutonic or intrusive rocks generally, are included under the pink colour on the map. Of these the greater part may be classed as true granites, but considerable areas of dioritic rocks also occur, with some of gabbro. Our knowledge of these rocks in this district is as yet insufficient to enable the several classes to be separately indicated on the map. This must, indeed, always remain a very difficult task in some cases, for a passage of granitic rocks into diorites may often be noted, particularly about the margins of the granitic areas, where these appear to have absorbed large portions of the more basic materials of adjacent old volcanic rocks of the stratified series. As elsewhere explained, a similar practical difficulty has been found in drawing any exact line between some of the granites and the gabbros and mica-diorites of the Cherry Bluff mass.

How distinguished on the map.

All the rocks thus grouped together bear very similar relations to the stratified rocks of the district, having altered and otherwise affected those among which they have been intruded. They are, however, not all of one age. The larger granitic masses of the Coast Ranges and of the Interior Plateau are evidently due to a period subsequent to that of the Nicola (Triassic) formation and antecedent to that of the Earlier Cretaceous. In this respect they agree with the great granitic masses which have been studied on the outer margin of the Coast Ranges along the Pacific border of British Columbia.* They are probably coeval with these and due to the same orogenic causes.

Age of granite rocks.

The Cretaceous rocks are, however, also in some places broken through by granitic masses, rendering it evident that a portion of the granites must be much more recent in date. Granites of this age may occur in many places where the absence of the Cretaceous rocks renders it impossible to determine their age, for no means has yet been found of differentiating these granites petrographically from those of the earlier period.

It is also certain, that granitic rocks due to periods much earlier than the Triassic must occur in some parts of the region, for even in the Cambrian strata, rocks largely composed of granitic debris are found (p. 108 B). Some of the gabbros and diorites again, are believed to represent the deep-seated products of the Tertiary period of volcanic activity.

Perhaps the most notable fact which appears on assembling the numerous observations made, is that of the existence of two zones in

Notable hornblende zones.

* Annual Report, Geol. Surv. Can., vol. II. (N.S.), p. 152.

which highly hornblendic rocks, often true diorites, are specially prevalent. The first of these runs near to and parallel with the Fraser River, though generally on its east side. It may be regarded as including a great part of the Lytton Mountains, Botanie Mountain and its northern continuation, the plutonic rocks met with between the vicinity of Fountain and Pavilion Creek and those found near Leon Creek. The second zone of the same kind, runs nearly parallel with the Nicola and part of the Thompson River from the Promontory Hills to the vicinity of Ashcroft.

Their probable origin.

The first of these zones is undoubtedly connected at no great depth with the truly granitic rocks of the Coast Ranges on the west, the second blends to the eastward with the large mass of true granites which occupies the area between the Nicola and Guichon Creek. In the first, numerous cases occur where the intrusive material is inextricably mixed with much-altered greenstones and other bedded rocks, while infolds and lenticular masses of now crystalline schists, (some at least of which doubtless represent bedded materials) are abundant in it. In the second, these conditions are not so clearly apparent; but in both, it is probable that the present character of the rock is largely due to the absorption, or granitic fusion nearly in place, of great masses of the basic materials of the older formations. In some other instances, the plutonic rocks are clearly eruptive, sharply defined and quite different in character from the older materials which they break through, while many cases of an intermediate character present themselves, where no sound judgment appears possible as to the relations in this respect of the two classes of rocks.

Peripheral effects of pressure.

It is very generally observed, that the borders of the areas of granitic and other plutonic rocks, afford evidence of intense pressure, both in the foliation imparted to these rocks themselves and in the effects produced in the neighbouring stratified rocks, one of which is a tendency to parallelism of the strike of these rocks to the line of junction. This is not only the case in the strictly folded region of the Coast Ranges, where both classes of rocks appear to have been subjected, perhaps at several periods, to a common compression, but also in that of the plutonic masses of the plateau region, where the evidences of a general compression are much less distinct. Whether these peripheral effects are due to a pressure exerted by the plutonic rocks themselves, or whether the extrusion or granitic fusion to which such rocks must be attributed relieved a formerly existing pressure when it occurred, the facts appear to be insufficient to decide.

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Rocks ascending

In later pages such brief details as appear to be necessary are given for the several plutonic areas. The clearly apparent fact that the development of veins holding metalliferous minerals is largely dependent on proximity to such areas and the hydrothermal or other similar action which has been set up during the formation or intrusion of these masses, renders their definition a matter of some economic importance. It is, further, highly probable, that when the metalliferous veins are better known and more extensively worked, it will be found possible to trace differences in their character dependent on the differing composition of the various crystalline masses near them.

Connection
with ore-bearing
veins.

Intrusive rocks of the character of dykes, occur in great numbers in many parts of the entire region, and in almost endless variety in respect to composition; but in the present preliminary state of our knowledge of the region, it is judged to be unnecessary to detail observations upon these rocks or to enter at any length into the examination or description of them. At some future period a study of these dyke rocks may be undertaken, which may not be without results of importance, but, in common with many other detached lines of investigation, it has been found necessary to relegate this to later observers.

DESCRIPTIVE GEOLOGY.

In this division of the report, such local details as appear to be of importance are given, and the data relied upon in laying down the geological lines in different parts of the field are discussed. The observations referred to are generalized as far as possible, but they are required in order to supplement the broad indications afforded by the map. The order of description adopted is not strictly that of relative age throughout, as it is more convenient to arrange the matter in some cases in correspondence with locality. Generally speaking, however, the Palæozoic rocks are first noticed, and these are followed by the Triassic, the Cretaceous and the Tertiary; rocks classed as Plutonic coming last. The drift deposits or Pleistocene are noticed in a subsequent chapter.

Order of treatment.

PALÆOZOIC ROCKS.

Thompson Valley--In-ki-kuh Creek to Cache Creek.

Rocks referred to the Cache Creek formation, are first met with in ascending the Thompson Valley about six miles above Spence's Bridge, and are continued to the Cache Creek.

Disturbed
rocks on the
Thompson.

where they emerge from beneath the Miocene volcanic materials and occupy a narrow interval between this and the great granite mass to the eastward. They occur on both sides of the river, and numerous exposures may be found, but all are so much broken and disturbed that nothing can be said with certainty as to their general arrangement. The main direction of strike is about N. 20° W., and most of the observed dips are to the westward; it is therefore probable that the higher beds occur in that direction. There is reason to believe that faulting has occurred along the line of the Thompson or that of Venables Valley, and perhaps in both places.

Fossiliferous limestone.

The rocks consist of gray limestone, with greenstones, sometimes more or less schistose, cherty quartzites, which often show locally an extreme stage of alteration and shattering, and hard, black slaty argillites. The bed of limestone which appears on the wagon-road two miles and a half above the 89-mile stake, is that particularly referred to in Dr. Selwyn's original report, from which some fossils were at the time collected by Mr. Richardson. Among these the following genera were recognized:—*Cyrtina*, *Spirifera*, *Rhynchonella*, a small *Myalina* and a *Euomphalus*. Respecting these Mr. Billings wrote:—"Although none of the above have been determined specifically, they indicate almost certainly a horizon between the base of the Devonian and the summit of the Permian."*

Venables Valley.

Along Venables Valley, greenish, somewhat schistose rocks, with gray and blackish argillites were found. These appear to underlie massive limestones, which occur in the hills on the west near the head of Twaal Creek and in White Mountain.

Shattered and decomposed rocks.

In following the wagon-road northward, the rocks all along this part of the Thompson Valley are found to be excessively shattered and decomposed. Red, yellow and white crumbling banks often appear in gullies and on hillsides, composed of rocks which have been completely crushed and often pyritized or silicified. Later hydrothermal or solfataric action, resulting in the decomposition of the pyrites and the leaching of the mass by acid waters, has given rise, opposite Spatsmum station, to a deposit of china-stone with kaolinite and gypsum, which is again referred to in connection with the economic minerals of the district.

China-stone.

Pyritized rocks with traces of gold.

To the north of Jack's Creek, similar alteration has affected the rocks on both sides of the road. On the east, the Red Hills show crumbled quartzites highly charged with pyrites. On the west, the crushed

* Report of Progress, Geol. Surv. Can., 1871-72, pp. 61-62.

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rocks extend for nearly two miles and appear to be composed largely of quartzites, or at least of rocks now so highly silicified that they resemble quartzites. As noted on a later page a specimen of these rocks proved to contain traces of gold. With these are quartzose schists, often quite lustrous, but some of which still evidently represent fragmental materials like some of those found in a less altered condition in association with the limestones near the 89-mile stable. These rocks are here in general nearly vertical, with a north-north-west strike, and they have evidently been subjected to great pressure in a direction at right angles to the strike. They are probably folded, but it is impossible to trace out individual beds for any distance.

The edge of this greatly disturbed belt of rocks is found at this place at or near the small granitic intrusion shown on Jack's Creek. Edge of disturbed belt. To the west of this, the beds are comparatively undisturbed, and it is highly probable that one or possibly several faults, running about north-north-west along this part of the valley, coincide with this change in condition.

The zone of greatly disturbed and altered rocks above described, runs parallel with this part of the Thompson for fifteen miles or more, generally to the west of the river. The dynamic forces which have acted upon the rocks have in some places produced schists, while in others, and generally more or less lenticular areas, the strata have become crushed and comminuted.

Twaal and Blue-earth Creeks.

The hills about the sources of Twaal Creek and those along the north side of Blue-earth Creek, are almost exclusively composed of limestone. Extensive limestone exposures. In the last mentioned locality, gray limestone which is in part converted into marble, forms bold whitish cliffs facing southward, much resembling some of the cliffs along Marble Cañon. The openings of several caves or grottoes were observed high up in these cliffs. At the lower end of the little lake in which Blue-earth Creek rises, gray, probably concretionary chert is associated with the limestone and in this there occur many specimens of *Lophospira* with some *crassatella*, beautifully preserved.

At the mouth of Blue-earth Creek, the limestones are found to dip westward at high angles. They run thence to the north, along the Hat Creek valley, still forming bold cliffs to the entrance of the pass which leads eastward by way of Jack's Creek to the Thompson. At the entrance to this pass, on Hat Creek, the limestone was again found to Section along Jack's Creek.

dip westward, at a very high angle. Beginning at this place it was endeavoured to obtain a general section across the range of hills to the Thompson Valley, but with unsatisfactory results. The rocks seen are chiefly limestones, but, where their attitude could be ascertained, they appear to lie generally at low undulating angles, in such a manner that no great thickness is brought to the surface. With the limestones are interbedded hard, fine-grained, green, felspathic rocks, some of which are much decomposed diabase-porphyrites.* These are sometimes slightly schistose in structure and usually very much slickensided. There appear to be at least two important beds of this kind, one of them probably 300 or 400 feet thick, the other forming the lowest rock seen, but only in part exposed. Black schistose argillites and cherty quartzites were also seen, but not in great volume. Rocks of this kind were particularly noted near Limestone Amphitheatre, and again near the small granitic intrusion to the eastward, and between these places the beds appear to have the form of a shallow syncline about two miles in width. Some cherty masses occur in the limestones themselves, and in these crinoidal remains have been preserved.

To the east of the granitic intrusion just mentioned, the much altered rocks of the Thompson Valley begin, as previously explained (p. 81 B). Limestone cliffs are characteristic of the north side of this valley as of that of Blue-earth Creek, and at the Amphitheatre they assume remarkably picturesque forms.

Medicine Creek, McLean Lake, Cornwall Creek.

Cornwall
Hills and
vicinity.

Continuing to the northward, the older rocks observed in a few places to the east of the Tertiary of Hat Creek and south of Medicine Creek, are chiefly gray limestones, with some diabase-like green rocks resembling those last described, and occasional exposures of cherty quartzite. The dips are generally high and varied in direction.

The summit of the Cornwall Hills (6600 feet), was reached by ascending from Jack's Creek along the ridge overlooking the Thompson Valley. The higher part of the hills is open sub-alpine country, with numerous bare limestone outcrops and some minor exposures of greenstone and cherty quartzite. These rocks as a whole are probably about the horizon of the base of the Marble Cañon limestones.

North of Medicine
Creek.

North of Medicine Creek, between the two areas of Tertiary shown on the map, green altered diabases, sometimes agglomeritic, with

*Appendix I, No. 6.

DAWSON.]

cherty quartzite, not improvable N. 40° W. greenstone

In the observed, gray limestones but a narrow and a half agglomerate fragments to be over the Cattle chiefly of often more average, ab

The limestone have not been this here, a bodies of limestone of the base

In following concealed in cherty quartzite of serpentine on the north The surrounding the whole sections of the

Between the dorf's, on the strike of the obliquely across road. This irregularities has so far the thickness of necessary to

cherty quartzites, were the only rocks actually seen, but limestones may not improbably also occur here. The strike is pretty constant at about N. 40° W., and the beds are nearly vertical. The interbedding of the greenstones with the quartzites was clearly seen at one locality.

In the vicinity of McLean Lake, the older rocks consist, so far as McLean Lake. observed, chiefly of greenstones, probably diabase in composition, and gray limestones. The attitudes of these rocks are rather irregular, but a nearly east-and-west strike is found in some places. A mile and a half south of McLean Lake, quartzite-schist and greenstone agglomerate were found, the latter containing numerous limestone fragments and some circular crinoid joints. One of these was observed to be over three-quarters of an inch in diameter. The hills separating the Cattle Valley from that of the Bonaparte, are likewise composed chiefly of limestones and interbedded greenstones, the latter being often more or less distinctly schistose. The strike is here on the average, about N. 35° W., with high south-westerly dips.

The limestone areas shown upon this part of the geological map have not been strictly defined. It would be very difficult to accomplish this here, and the intention is merely to indicate the existence of large bodies of limestone. The horizon is again, in all probability, about that of the base of the Marble Cañon limestones.

In following down Cornwall Creek, from McLean Lake, after a concealed interval of a couple of miles, the rocks seen are principally cherty quartzites, with some fine-grained greenstone and a bed or beds of serpentine. A rather prominent little hill of gray limestone occurs on the north side of the stream before the wagon-road is reached. The surrounding rocks are cherty quartzites and quartzite-schists, but the whole so irregular and so much broken up that the order or relations of the several rocks could not be determined.

Cáche Creek to Mundorf's.

Between the western edge of the Ashcroft Cretaceous area and Mundorf's, on the wagon-road, a distance of some fifteen miles, the general strike of the rocks, which is about north-north-west, carries them obliquely across the line of the Bonaparte River and that of the wagon-road. This general strike is, however, subject to numerous subordinate irregularities, while the angles of dip met with are very varied, and it has so far proved impossible to define, with any accuracy, either the thickness of the strata met with or their general succession. It is thus necessary to describe these rocks as a whole and in general terms. It

would appear that numerous smaller folds are here superposed on the main flexures of the beds, and that there is thus a tendency for each zone of rocks, to occupy occasionally, a narrow or wide belt of country, in such a manner that the actual thickness could only be ascertained (if at all) by a most minute survey of the whole area.

Cherty
quartzites.

The most characteristic material is here a cherty quartzite or silicified argillite, which is generally found in thin beds of blackish or gray colour. These are separated by black, more or less lustrous argillite-schists, or by gray, glossy schists; and with them are interbedded one or possibly two beds of green or blackish serpentine. These rocks appear to cross the Bonaparte with a north-westerly strike to the north of the small outlier of Tertiary rocks marked on the map and described on page 213 B. Further west, they gradually turn to a north-eastward direction near Cache Creek, where they are much disturbed and corrugated. They next assume a north-north-westerly strike, and with dips which are in the main to the westward, cross the Bonaparte above the Indian village and occupy the lower part of the valley of Hat Creek between the river and the fault which here appears to bound the older Tertiary rocks to the eastward. The thickness of the rocks included in this belt, chiefly cherty quartzites, may be stated as probably from 4000 to 5000 feet. To the westward, near the Tertiary outlier above alluded to, and on the western slopes of the hills near Campbell Hill and declining to the Cattle Valley, the cherty quartzites and their associated rocks are followed, and apparently overlain, by interbedded green and green-gray diabases and limestones, in beds of small or medium thickness, which are carried by their strike beneath the older Tertiary rocks.

Conglom-
erate.

At five miles and a half below Hat Creek, about half a mile west of the wagon-road in the Bonaparte Valley, some exposures were found of a peculiar coarse greenish-gray conglomerate holding rounded pebbles. This rock has suffered considerable metamorphism, and appears to have been included in the flexures of the older rocks, but, as it holds some cherty quartzite pebbles, it may represent an outlier of some newer bed—possibly referable to the Nicola formation.

Rocks prob-
ably overlying
quartzites.

For about two miles to the north of Hat Creek, on the west side of the Bonaparte, the hills continue to be chiefly composed of the cherty quartzites. Beyond this point, to Mundorf's, the character of the rocks becomes more varied, and they are, in all probability, referable to a somewhat higher stage in the formation. As no persistent attempt to work out the stratigraphy in detail has yet been made, the rocks as a whole may be described in the following general terms, quoted from my report of 1877 (p. 93 B):—

"Between exposures of bedding impure, colour. inches in originally layers in or less so which has matter. found in * * * both in limestone and with been segre-

About nearly has crumbling oxidation

On the a rather in Creek a s toward th this creek schists an and varyi

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"Between Hat Creek and 124-mile post (Mundorf's) numerous exposures in the roadside show the intimate association and inter bedding of the cherty siliceous rocks with serpentines, pure and impure, and of the latter with volcanic breccias of greenish-gray colour. Some of the fragments in the breccias are from four to six inches in diameter, while in other beds the material is fine, and must originally have been of the character of volcanic sand. Schistose layers in the breccias have a greasy lustre, and appear to have more or less serpentine developed in them, while portions of the fragments which have been vesicular are now filled with soft green chloritic matter. An igneous rock similar to that forming the breccias is found in other beds in a compact state, of dark gray-green colours. * * * Lenticular masses and streaks of limestone occur, both in the breccias and serpentines. They do not resemble the limestone found elsewhere in the formation, being highly crystalline, and without any trace of organic origin. They may probably have been segregated in the mass."

About two miles and a half above Hat Creek, for a width of nearly half a mile, the rocks are very much shattered and decomposed, crumbling down into yellow and red banks, in consequence of the oxidation of iron pyrites with which they have been charged.

On the opposite side of the Bonaparte, in this part of its length, a rather important outcrop of limestone occurs. This crosses Scottie Creek a short distance above its mouth, with an arcuate form, convex toward the river. It is prominently seen in the hills to the north of this creek, where it is separated from the river by outcrops of gray schists and quartzites, which, though they present somewhat confused and varying attitudes, probably underlie the limestone horizon.

Bonaparte Valley above Mundorf's, and Glen Hart.

At Mundorf's, the main wagon-road leaves the Bonaparte and follows Glen Hart to Clinton. In the valley of the Bonaparte, northward to the Chasm, where it becomes occupied by Tertiary volcanic rocks, beds of the same character with those just described continue. Along this part of the valley, which is about thirteen miles in length, there appears to be a reasonably good opportunity of working out a general section of the strata represented, which are evidently referable to the same part of the Cache Creek formation with those to the south of Mundorf's; but, so far, little has been added to the results of the preliminary examination of 1877. Cherty quartzites of the usual character preponderate, often with blackish or gray shaly partings

Between Hat
Creek and
Mundorf's.

Crushed
rocks.

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Bonaparte
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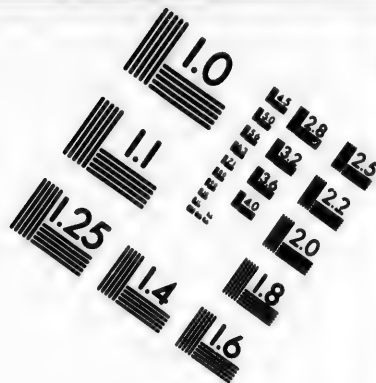
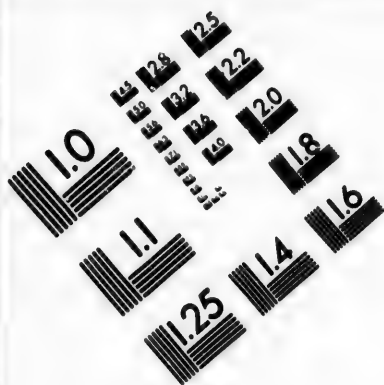
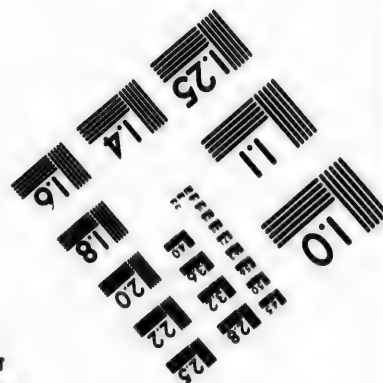
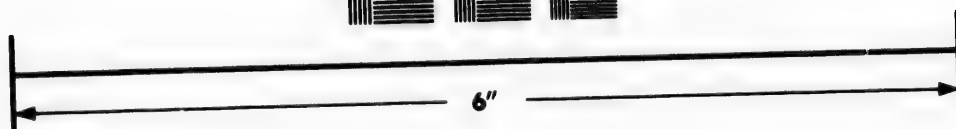
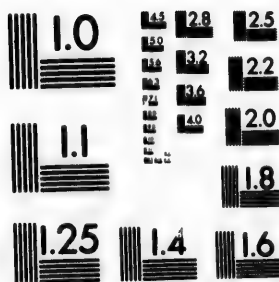


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Occurrence of
serpentine.

between their bedding planes. With these are interbedded greenstones, often agglomeritic, together with gray ash rocks, now more or less schistose, limestone beds and serpentines. The serpentine bed (or beds) is evidently most closely associated with the rocks of volcanic origin, and is no doubt derived from the alteration of some volcanic rock. The strike is in the main north-west by south-east. The sub-joined section, sketched at a place two miles above Loon Creek, and which appeared in the report for 1877, is reproduced here because of its interest in connection with the mode of occurrence of the serpentines of this formation. The bed of serpentine here represented is about 100 feet in thickness. No characteristic fossils were found in the particular bed of limestone included in the section, but about a mile further down the river, in another outcrop which may possibly represent the same bed, good specimens of *Fusulina* were discovered. This outcrop is associated with altered volcanic rocks but no serpentine was actually observed. The mass of the limestone is largely composed of crinoidal fragments, and several smaller species of foraminifera are present, including a form which is in all probability a *Trochammina*.



FIG. I. SKETCH SECTION SHOWING THE MODE OF OCCURRENCE OF SERPENTINE IN THE CÂCHE CREEK FORMATION.

a. Serpentine. b. Quartzite. c. Pale serpentinous schist. d. Greenish amygdaloid and breccia. e. Limestone.

Mundorf's to
Maiden
Creek.

Schistose
rocks in Glen
Hart.

Origin of the
schists.

In following the road from Mundorf's through Glen Hart, toward Clinton, the rocks continue to resemble those above described, about as far as the mouth of Maiden Creek; greenstones and cherty quartzites being most abundant. Thence northward, their character becomes somewhat changed. A schistose or slaty structure is in most cases observable, while very thin and flat divisional planes are developed. These as a rule correspond with the original bedding planes of the rocks, which are frequently still recognizable, but to which the schistose structure has been superadded by subsequent stress. The dips are here also found to be at very moderate angles of inclination, and while the valley as a whole follows the strike of the beds, this occasionally turns abruptly to bearings almost exactly transverse to the valley. The rocks consist chiefly of gray and greenish schistose materials and of black glossy argillites. The gray schists are evidently composed of squeezed volcanic ashes, while the greenish schists are clearly an alter-

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ation-product of the ordinary greenstones or diabases; but along this part of the valley the cherty quartzites before so common, were not seen. The black glossy argillites precisely resemble those found along the Bonaparte Valley, and in regard to the gray schists, a less squeezed material of the same kind, and more evidently clastic, was found to occur about a mile below Mundorf's, in the Bonaparte Valley.

The problem presented by the rocks here met with, is whether they represent a peculiar condition of alteration of materials of the same age with those already described, or whether they may belong to a different and an older series, for, if it be admitted that their present appearance is of classificatory value, they very closely resemble lithologically certain rocks found along the Fraser River (particularly those in the vicinity of Anderson River and Boston Bar, to the south of the Kamloops sheet) which were originally assigned to a very low stage in the Palæozoic. So far as I can see from our present knowledge of the subject, no reason can be urged for the supposition that these particular rocks are older than the rest. It would appear that they have been to a great extent exempted from the silicifying changes which has resulted in the production of the cherty quartzites from ordinary argillites, while they have been instead affected by pressure, giving rise to a dynamic metamorphism, which in all probability occurred at an earlier period than the silicification.

Probable relations of these rocks.

At the north end of the little lake situated about a mile to the south of Round Lake, a bed of gray crystalline limestone about thirty feet in thickness occurs, and is interbedded in schistose rocks of the character just described.

In ascending Hart Ridge from Clinton, rocks like those of Glen Hart Ridge are occasionally seen, though the surface is much covered by drift. Along Junction Valley, from Clinton to the Bonaparte, the rocks seen are chiefly quartzites and greenstones, resembling those of the Bonaparte, and offering no features of special interest.

Marble Cañon and Vicinity.

In the report for 1877, an attempt was made (in section No. 5), to give a diagrammatic representation of the relations of the rocks occurring between Lillooet, on the Fraser River and the mouth of Hat Creek on the Thompson, via Marble Cañon. Subsequent investigations show that some of the features represented in the western part of this section require modification, particularly in respect to the now recognized Tertiary age of the porphyrite rocks, which

Section 1877.

in 1877 were supposed to be attached to the Cretaceous series, but in the main, that part of the section which runs eastward from the west end of Marble Cañon, is still believed to afford a general idea of the structure. A short description of the older or Cache Creek rocks shown in the Marble Cañon section, from the Fraser at the mouth of Pavilion Creek eastward, will therefore here be given, based in part on that contained in the report of 1877, with the omission of some details which may not require repetition and with the addition of some new facts since ascertained.

Mouth of Pavilion Creek.

From the fall, near the mouth of Pavilion Creek, for a distance of about three miles and a half eastward, or to about a mile beyond the bridge crossing Pavilion Creek, the rocks may be described as consisting chiefly of hard green or gray-green altered diabases, of rather fine grain. With these rocks, a short distance above the fall, a couple of thin limestones are interbedded and some thin layers of quartzite, all very irregular. One of the limestones is again found to the southward, about half-way between Pavilion Creek and Eighteen-mile Creek, on the road.

Intermingling with diorite.

In the hills between Eighteen-mile Creek and the south side of Pavilion Creek, these rocks are very largely mingled, in a perplexing manner, with greenish granitoid diorite. A careful examination of the rocks, appears to show that in this place the plane of the present surface nearly coincides with that of the upper part of an intrusive mass, or that of a centre of alteration, where the diabase-like stratified rocks are everywhere penetrated by apophyses of a dioritic character and have been perhaps in the process of fusion with such a crystalline rock. The circumstances are in fact such, that it is often impossible to draw a definite line between the altered stratified materials and those classed as eruptive. The area thus characterized is specially designated on the map.

Cherty quartzites.

Half a mile above the bridge on Pavilion Creek, another projection of highly altered and confused rocks like those just described, crosses the valley. This is about half a mile wide, and the dioritic material becomes predominant in its eastern part. Beyond this, for a mile, the rocks are gray cherty quartzites, silicified argillites and black argillite-schists, all considerably crushed and often weathering rusty. These appear to strike across the valley almost at right angles and are generally vertical or very nearly so.

Granitic intrusion.

A short distance east of Captain Martley's house, the section is interrupted by a granitic intrusion, which holds angular fragments of

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* Repy Soc., vol. X

the stratified rocks in some places, and extends for about two miles along the valley, surrounding the lower end of Pavilion Lake.

This granite is followed by hard, somewhat lustrous and schistose argillites, which are cherty in some layers and dip N. 75° E., at angles of 70° to 80°. The thickness of these rocks to the east of the granite is not very great. They are succeeded, apparently in ascending order, by a great mass of limestone, which continues in almost uninterrupted exposures in the sides of Marble Cañon from this place to its eastern end, on Hat Creek—a distance of about seven miles by the valley, or five, at right angles to the strike of the beds. Throughout this distance the limestones occur almost to the exclusion of other beds, though in a few places holding slaty or schistose intercalations of small width. The limestones or marbles, into which they occasionally pass, are usually so massive that it is impossible to determine their dip, but that they are much folded together appears to be certain. An example of such folding, in which a small acute anticline comprising some slaty beds and quartzites has been overturned to the eastward, is figured and described in detail in my report of 1877 (pp. 90 B-91 B). This occurs in the front of the hill on the north side of the east entrance to Marble Cañon, close to Hat Creek.

Massive lime-
stones.

Their flexures.

In the limestones of Marble Cañon, Mr. James Richardson, in 1871, collected specimens containing the remarkable Foraminifer which was subsequently described by me under the name of *Loftusia Columbiana*.^{*} The microscopical examination of numerous thin sections of the limestone, led also to the discovery of characteristic specimens of *Fusulina*, rendering it probable that the *Loftusia* may be accepted as equally characteristic of a Carboniferous age. Besides the above forms, no recognizable fossils except the joints of crinoidal columns, have been obtained from these massive limestones.

Loftusia and
Fusulina.

In regard to the mode of occurrence of the *Loftusia* and its importance as a limestone builder, the following extract may be quoted from the paper last above referred to:—

Character of
Loftusia lime-
stone.

"In certain beds of the limestone of Marble Cañon, the *Loftusia* occurs almost to the exclusion of other forms, characterizing the rock, and having been the agent in its production, just as *Fusulina* occur in the best examples of *Fusulina* limestone or Globigerine in the Atlantic ooze. Other beds of a nearly white colour and almost porcellaneous aspect on fracture—though purely calcareous—are found on microscopic examination to consist of the comminuted remains of

^{*} Report of Progress, Geol. Surv. Can., 1877-78, p. 88 B. Quart. Journ. Geol. Soc., vol. XXXV., p. 69.

smaller Foraminifera, the mass resembling a thoroughly hardened chalk. Through these a few more or less perfect *Loftusia* may be scattered. *Fusulina* appear to be very scarce in the Marble Cañon limestones; they are much more abundant in those of other parts of the country, composed principally of crinoidal fragments. They seem to have preferred a bottom composed of the debris of the larger calcareous organisms to the fine oozy bed most congenial to the *Loftusia*."

"The typical and most abundant form of *Loftusia* limestone is a pale or dark gray crypto-crystalline rock, in which the more perfect specimens of *Loftusia* appear thickly crowded together as paler spots, generally pretty sharply defined. The limestone breaks freely in any direction, the fracture passing equally through the matrix and included organisms, which it is impossible to separate from the stone. The matrix generally seems to be composed in great part of granular calcareous matter similar to that employed in building up the test of the *Loftusia*, but more irregular in size of grain, and with an occasional fragment of a Crinoid or example of smaller Foraminifer."

East edge of
limestone
belt.

In following down the valley of Hat Creek, in a north-easterly direction from the eastern end of Marble Cañon, similar limestones are found to continue for about three miles, or till they become covered by the Tertiary rocks in that direction. The limestones here include at least one bed, which must be over a hundred feet thick, of fine-grained gray-green felspathic rock, originally volcanic.

Further down Hat Creek, a small projecting ridge of the older rocks which appears from below the Tertiary conglomerates, is chiefly composed of hard green agglomerate, though to the north of the valley it consists almost entirely of limestone. The cherty quartzites and associated beds met with near the mouth of the creek have already been noticed (p. 84 B).

General ar-
rangement
and thickness.

The rocks included in the whole section above described, between the Fraser and the Bonaparte, are believed to hold in the main a synclinal form, though with many irregularities and minor complications. The structure is at least undoubtedly a syncline, one between the Pavilion Creek granite and the main western edge of the Tertiary rocks. Of this the limestones hold the whole central and stratigraphically higher part. Taking the actual distance across the strike, which is pretty uniformly north-north-westward, with the average inclination given by the few observed dips, the thickness of the limestones would appear to be about thirteen thousand feet. But there

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is every reason to believe that they are in reality affected by numerous subordinate flexures, and that though very thick, the entire mass may not even reach half the amount stated.

Mount Martley and Chi-poo-in Mountain.

The facts ascertained respecting the older stratified rocks in the adjacent mountains, necessarily somewhat imperfect, may now be briefly noted in connection with the Marble Cañon section.

The central parts of Mount Martley and Chi-poo-in Mountain are composed of a mass of gray granite. To the west of this granite mass, the rocks consist chiefly of cherty quartzites and hard blackish and gray argillite-schists, interbedded with limestone, which preponderates toward the edge of the granite. The quartzites and argillites are evidently continuous with those seen on Pavilion Creek near Captain Martley's house. The strike is about north-and-south, and the beds are vertical, or very nearly so, wherever examined. To the north-east of the granite area, a lower range of hills, composed apparently almost entirely of limestone, separates it from Marble Cañon. Where close to the edge of the granite, near Hat Creek, the limestone was observed to be locally changed into coarse, or fine grained, gray and white striped and blotched marble; but this is apparently too much broken up to be of any value. Some quartzites and schists were also found interbedded with the marble in this vicinity.

Rocks surrounding granite mass.

To the south of the same granite mass, on Chi-poo-in Mountain and along the north side of Limestone Creek, limestones again preponderate. They are associated with some greenish or blackish diabase-like rocks, and with small beds of black argillite-schist and cherty quartzite. The limestones are altered, as in the case last described, near the actual edge of the granite. They dip southward at high angles.

It will be observed that there is a tendency for the limestones and associated stratified rocks to dip away from the granite in all directions. One very small outlier of marble was found patched upon the granite to the west of the summit of Mount Martley, and it is probable that others of the same kind occur in this high region.

Dips away from granite.

Pavilion Mountains.

The southern slopes of the Pavilion Mountains, east of the Pavilion Creek granite, are all remarkably free from drift deposits. They were well seen from several high points, and appear to consist entirely of limestone, though there are doubtless also minor intercalations of

Pavilion Mountains limestone.

other materials, as elsewhere found. In crossing these mountains by the upper valleys of Pavilion Creek and Maiden Creek, limestone is again found almost to the exclusion of other rocks, though occasional exposures of black schists, cherty quartzite and greenstone also occur. The two last-named rocks were noted to be particularly abundant near the sources of Pavilion Creek and close to the summit of the pass, but the higher hills and larger exposures everywhere consist of limestone, precisely resembling that of Marble Cañon. Tail-salt Ridge, seen only from a distance, where not capped by Tertiary volcanic rocks, appears likewise to consist of similar limestones.

Junction Valley.

The rocks of the eastern part of Junction Valley have already been mentioned in connection with those of the Bonaparte and Glen Hart (p. 85 B). To the west of Clinton, this remarkable valley crosses the direction of the Marble and Pavilion Mountains and the general strike of their component rocks, nearly at right angles. Its western end is occupied by the lower part of Kelley Creek.

Rocks west of Clinton.

For about four miles west of Clinton, the mountains on both sides of the valley are practically wholly composed of limestone, and for a further distance of about four miles, nearly to the point at which the road turns up Kelley Creek valley, the same may be said with regard to the upper parts of the mountains at least. The valley itself is wide, and the exposures seen are few and poor unless the slopes are ascended. In an exposure midway between the forty-fourth and forty-fifth mile-posts from Lillooet, in the valley, scattered specimens of *Loftusia Columbiana* were detected in a gray limestone, which here dips S. 64° W. < 60°. About two miles to the east of Kelley Lake, on the northern side of the valley, a short section, about two miles and a half in length, was carefully examined and measured in 1877, the exposures on the hillside at this place appearing to be more continuous than usual. A note on this section is given in the report for 1877-78 (p. 95 B), but it proved to be impossible to arrive at certainty in regard to the thickness or order of superposition of the beds, because of the great amount of disturbance to which they have been subjected. It shows, however, the intimate association of the massive limestones with blackish to pale-greenish cherty quartzites or hornstones, quartzose and felsepathic schists, and greenish or grayish-green decomposed diabases or felsites. Some of the beds are serpentinous in joints and cracks, and small quantities of chrysotile or serpentine-asbestos were observed in one place. The section as a whole is supposed to be near

Disturbance and complication of beds.

the base of the horizon.

To the south of the Pavilion Creek valley, argillite is breaking out in these areas, and is noticed in the referred angles of Kelley Fraser, are all of a quartzite. This, known

To the south of the Pavilion Creek valley, argillite is breaking out in these areas, and is noticed in the referred angles of Kelley Fraser, are all of a quartzite. This, known

On the above Leon Cr

the base of the Marble Cañon limestones and very probably about the horizon of that at the east entrance of Marble Cañon (p. 89 n).

To the west of Kelley Lake, the massive limestones are no longer found. About the lake and along the road which ascends the slope of Pavilion Mountain to the south, the rocks consist chiefly of blackish argillites, generally more or less schistose, often considerably silicified, breaking with a rough irregular fracture and weathering rusty. With these are cherty quartzites of the usual kind, in considerable abundance, and at Kelley Lake some greenstone, probably interbedded, was noticed. The general strike of these rocks along the road above referred to, is a few degrees west of north, with westerly dips at angles of from 30° to 70°. Similar rocks continue on the lower part of Kelley Creek, which falls rapidly in a very rough gorge to the Fraser, but cherty quartzites are, perhaps, more abundant here. They are all very much fractured, and near the edge of the Fraser contain a quartz-vein which an attempt has been made to work for gold. This, known as the Big Slide mine, is described later.

Rocks west of Kelley Lake.

Big Slide mine.

Fraser Valley, North of Kelley Creek.

To the north of the mouth of Kelley Creek, a small granitoid mass, about four miles in length, occupies a part of the Fraser Valley, and it will be convenient for purposes of description, to combine the notes made on both sides of the river from this place to that in which the valley enters the map-sheet. This granitoid mass is nearly in line with that found to the south of Pavilion Creek and east of the Fraser (p. 88 n). Its relation appears to be similar to the adjacent rocks, and these are all highly altered in its vicinity. Near its southern end, on the west side of the river, are coarse, almost gneissic rocks, apparently much metamorphosed diabases, hornblendic schists and hard gray quartzite. On the east side of the river, north of Kelley Creek and bordering on the granite, the rocks are chiefly cherty quartzites, but include diabase-like materials which appear to blend with the greenish granitoid mass, and one or more thin beds of limestone. It is impossible here to draw a distinct line between the eruptive and the stratified materials. Rocks precisely similar to those found at the south end of the granitoid mass occur about its north end, on the lower part of Leon Creek, but with the addition of a bed of limestone or marble about fifty feet in thickness.

Granitoid mass and surrounding rocks.

On leaving the vicinity of the eruptive rock, the excessive alteration above noted, ceases. The rocks on the west side of the Fraser, from Leon Creek to the edge of the map, consist chiefly of gray and black

North of Leon Creek.

cherty quartzites, generally in thin and regular beds, with black or blackish schistose, argillites which in some places preponderate over the quartzites. Some greenstones also appear and two outcrops of limestone, in beds of inconsiderable thickness, were noted. One of these occurs two miles above Leon Creek, the other almost exactly where the line of the edge of the map is drawn. The first of these, under the microscope, shows evidences of great pressure, but crinoidal fragments are distinguishable; the second may be called a marble. The strike of the rocks along this part of the valley, is pretty uniformly north-west; the angles of dip are usually high and the beds in all probability form several folds. On the east side of the Fraser, in the corresponding portion of its length, the rocks are precisely similar to those just described, though argillites are perhaps a little more abundant, and some instances of distinct slaty cleavage were observed in these.

Big Bar
Creek.

Further to the north and west, beyond the edge of the present map, argillites and quartzites of a similar character, with some diabase and occasional thin beds of limestone, are cut across nearly at right angles by Big Bar Creek. The valley of this stream appears to be a likely place in which to obtain a general section of these rocks.

Valley between Edge Hills and Marble Mountains.

The Edge
Hills.

The valley which separates the Edge Hills from the Marble Mountains, has been cut out along the general strike of the rocks and almost exactly on the line of junction of the argillaceous schists and quartzites on the west, with the massive limestones of the Marble Mountains on the east. In the northern part of the valley, the actual junction of the two classes of rocks is covered by basalt, but along the upper part of Kelley Creek, which flows in this valley, the line can be closely traced. The Edge Hills, by which this valley is separated from that of the Fraser, appear to consist entirely of the argillites and quartzites with their associated rocks, as described in the foregoing pages; the western part of Junction Valley, with the Fraser Valley, that of Big Bar Creek and the valley last referred to above, completing the circuit of these hills. To the northward, the trend of the Edge Hills turns more to the west, in conformity with a general change in the strike of the beds.

Haller's Mill.

At the extreme north-western angle of the map, a locality of some interest is found at Haller's mill. A gray fine-grained limestone occurs here, striking about N. 5° W. and dipping eastward at angles of 60° to vertical. The beds are so soon covered by basaltic rocks to the eastward, that it is impossible to tell whether this limestone actually

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forms a part of the massive series of limestones appearing in the Marble Mountains. but it cannot be far beneath their horizon. In the gorge of the stream, below the mill, the limestone is, however, found to be underlain by blue-gray cherty quartzites, which form a distinct anticlinal fold. In the limestone, not far above its junction with the quartzites, characteristic specimens of *Leptæa* were discovered.

Marble Mountains.

This high and broken range extends from the Junction Valley, in a north-north-west direction, for about twenty-five miles, its extremity lying just beyond the edge of the map. In its southern part, it has an average breadth of seven miles, but toward the north, it decreases in importance and eventually ends in a pretty acute point, the basaltic rocks of the plateau apparently running completely round it. These mountains are almost entirely devoid of surface covering, whether drift material or vegetation, and their general character as limestone masses may thus be clearly seen even from a long distance. In its composition the range precisely resembles the Pavilion Mountains, of which it is in fact the continuation. Its western side is bounded, as already explained, by a long and straight valley. The eastern side faces the great basaltic Green Timber plateau. Both sides were seen along their entire length, and everywhere the mountains appeared to consist wholly of limestone, though, undoubtedly, a closer examination would lead to the discovery of minor intercalations of other rocks. The limestones of the southern part of the range, along its eastern face, appear to dip westward at low angles. At the extreme head of Clinton Creek, in the centre of this part of the range, some yellowish and black cherty quartzites were found, dipping S. 65° W. < 60°, but the surrounding mountains still appeared to be composed almost entirely of limestone. To the west of Big Bar Lake, the mountains were again found to be composed of gray fine-grained limestone, and at the extreme northern end of the range a similar limestone is the characteristic rock, with an observed dip of N. 50° E. < 45°.

Almost entirely limestone.

There can be no doubt that this notable limestone range, like that crossed by Marble Cañon, forms a wide and well defined syncline, although the generally flexed character of the rocks in the vicinity, leads to the belief that numerous lesser folds may also occur.

Range a syncline.

One mile south of Sandy Creek, on the east flank of the range, a gray crystalline limestone was found interbedded with a silicified red argillite, the beds being vertical, with a north-and-south strike. These exposures attracted particular attention because of the

Traces of
gold.

resemblance of the red rock to certain loose specimens found near Clinton, which had proved to be richly auriferous, as noted later. Specimens collected from this place showed traces of gold on assay.

Outlying Areas to the Southward.

Having now traversed the principal area of development of the Palaeozoic rocks to the east of the Fraser, in as much detail as our present knowledge of them appears to render useful, two small outlying areas further to the south may receive a word of mention. Besides these, what remains to be said on the older rocks relates wholly to their representatives to the west of the Fraser, in the Coast Ranges or in their vicinity, and to rocks met with on or near the North Thompson River. The two localities above referred to are those at the head of the Botanie Valley and near the mouth of Iz-man Creek, respectively.

Head of Bot-
anie Valley.

In the first-mentioned place, in the hills about a mile due north of Botanie Lake, a coarsely crystalline gray or white marble was found, associated with hard green hornblendic rocks and with some of a schistose character. The strike appears to be about north-west. These rocks are here much cut up by granitic dykes and intrusions, but seem to represent a much altered stage of the ordinary greenstones and limestones. Similar green rocks, but without the limestone, were again seen on La-loo-wissin Creek, to the northward, and appear to form a part of the same insulated area.

Iz-man Creek.

On the east side of the Fraser River, nine miles above Lytton and on both sides of the lower part of Iz-man Creek, a number of exposures of much altered rocks occur. These are in contact to the eastward with the massive diorites of Botanie Mountain, and the total thickness shown must at least be greater than 500 feet. The rocks consist chiefly of sheared greenstones, probably representing an eruptive, glossy felspathic schists very finely laminated and green felspathic schists.

Palaeozoic Rocks of the Coast Ranges.

Composition
of Coast
Ranges.

To the west of the Fraser and south of Lillooet, a portion of the eastern part of the wide mountainous belt known as the Coast Ranges of British Columbia, is included in the present map. Exclusive of the Cretaceous strata near the Fraser, it has been found possible to separate the rocks met with in this rugged mountainous region into three classes, as follows:—1. Rocks which are evidently the representatives

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*Appendix

in a more or less altered state of the Palaeozoic formations already described. 2. Crystalline schists. 3. Granites.

The rocks of the first class are those which are here noticed, of those of the remaining two classes some description will be found in another place (p. 238 B).

Just opposite the area of rocks described near Iz-man Creek, and separated from it only by a narrow belt of the overlying Cretaceous, some much altered and corrugated beds are found near In-koi-ko Creek. These appear to have a width of about a mile, between the Cretaceous edge and the granite, though it was found to be a little difficult in this place to draw a line between the Cretaceous rocks and those of the older series. The latter consist of greenish and gray felspathic materials, sometimes with calcareous layers, and of quartzites, which are often nearly white and vitreous. The rocks are all much disturbed and are cut by numerous granite dykes before the main border of the granite is reached. This band of rocks continues northward, as shown on the map, gradually widening. Where it crosses Si-wei' Creek, it is composed chiefly of gray schistose quartzites, generally somewhat micaceous and corrugated, and of green rocks, also more or less schistose, but evidently resulting from the dynamic metamorphism of some of the ordinary greenstones. Some distance further up this creek, a small area was found by Mr. McEvoy of greenish and dark gray hornblendic and micaceous schists, which appear to represent still further altered conditions of the rocks just noticed and closely resemble some of those of Iz-man Creek.

In the vicinity of In-ti-pam Creek and Askom Mountain, the width of the belt of Palaeozoic rocks becomes nearly three miles, and at a short distance to the north of the creek, these rocks come down to the edge of the Fraser, the Cretaceous being locally confined to the east bank. The rocks are here chiefly gray and black, hard, somewhat schistose argillites, with cherty quartzites of the same colours. With these are, however, included important intercalations of gray-green felspathic rocks, representing the ordinary greenstones in an indurated condition. Two beds of serpentine (or two outcrops of a single bed) are also included in the section. One of these occurs a short distance north of In-ti-pam Creek, about half a mile from the river, the other about half way up the long ridge by which the summit of Askom Mountain was reached. The last-mentioned is distinctly schistose, and contains irregular harder layers, which, according to Mr. Ferrier, have the composition of saxonite.*

*Appendix I., No. 7.

Condition and
attitude of the
rocks.

Though somewhat irregular, the strike of all these rocks is generally north-north-westward, parallel to the main direction of the mountain ranges, with dips usually, but not invariably, to the westward. They are cut by numerous dykes, and are generally much shattered, with the development in them of considerable quantities of iron pyrites, the decomposition of which produces the general reddish colour by which Askom Mountain is characterized, in contrast with the usual gray colours of the granitic mountains of the region. On approaching the granite to the westward, the argillites become distinctly micaceous and glossy and are often corrugated, and together with the quartzites are everywhere cut through by numerous small quartz veins and seams. The broken and evidently crumpled character of the strata in this vicinity is such as to preclude any accurate knowledge of their order of succession or actual thickness, but the latter must be very considerable.

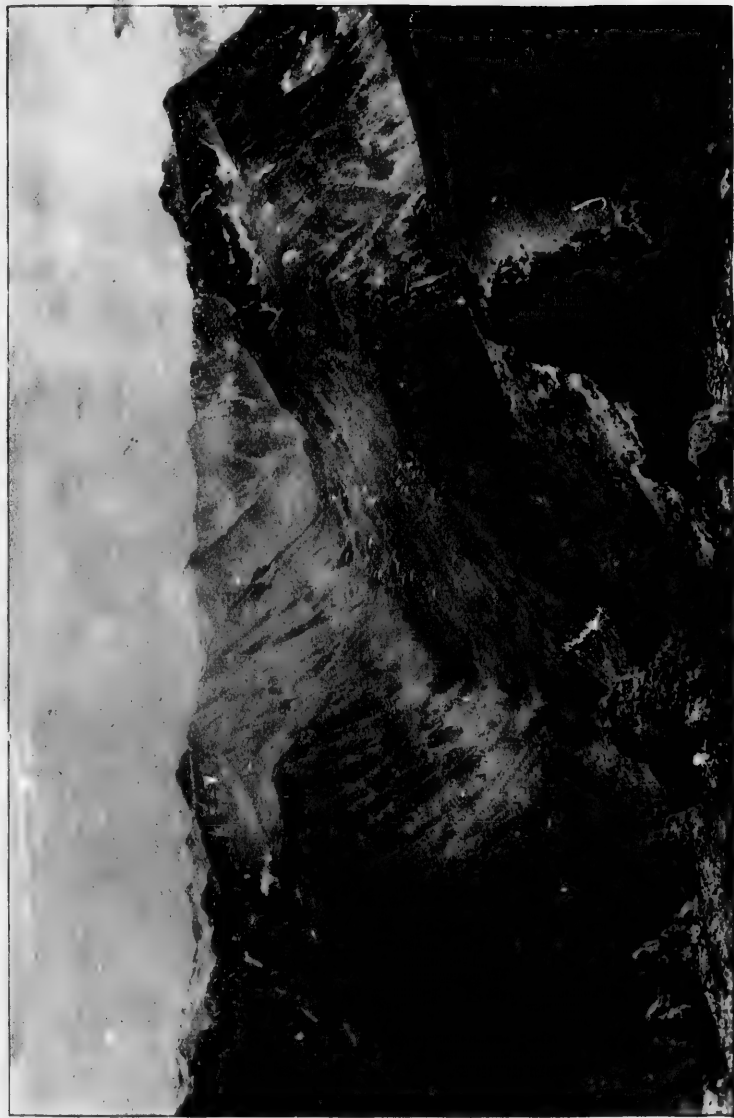
Evidently
Câche Creek.

The composition and association of the rocks at this place, however, leaves no room for doubt that the greater part of them at least, represent that portion of the Câche Creek formation which is characterized by cherty quartzites and argillites, with some greenstones and serpentines, and of which the character, as displayed along the Bonaparte and Thompson valleys, has already been described. Their state of alteration and present appearance is, however, practically identical with that of the Boston Bar rocks, as met with in the Fraser Valley to the south of the area of the present map (see p. 101 n).

Texas Creek.

Still further north, on the lower part of Texas Creek, the Palæozoic rocks appear as a narrow band between the Cretaceous (here very much shattered) on the east and a massive granite on the west. At the bridge by which the stream is crossed, they consist of gray-green felspathic tuffs containing films of interbedded black argillite, but all excessively twisted and kneaded together. To the west of the granite just referred to, which is quite narrow, the Palæozoic rocks again appear, and were found by Mr. McEvoy to extend westward for a width of nearly four miles, when they are again bounded by granite. The rocks here consist principally of blackish argillites, generally somewhat micaceous, and often becoming black micaceous schists. Some gray, possibly felsphatic, schists are also found and numerous small quartz veins were noticed. The rocks are nearly vertical toward the east side of this belt, but further west were observed to have westerly dips in a couple of places. The belt of Palæozoic rocks here crossed by Texas Creek, is evidently the same with that found further north on Cayoosh Creek, and there examined, and the auriferous character of the rocks on Cayoosh Creek renders their extension here important.

Relation to
Cayoosh
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VIEW IN THE COAST RANGES.
Looking Southward from Askom Mountain.

G. M. DAWSON.—Photo. July 26, 1890.

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In following the west side of the Fraser Valley from Texas Creek to Lillooet, much-shattered, gray, cherty quartzites, associated with a bed of serpentine, are found three miles north of Texas Creek. The strike of these rocks precisely accords with the direction of the valley, and they continue to appear along it at intervals for five miles, or to Cayoosh Creek. Hard greenstones also form a part of the series. The serpentines are particularly well shown near the road, about a mile south of Cayoosh Creek. The same bed of serpentine was again found a mile and a half beyond Cayoosh Creek on Hoey Creek, behind the town of Lillooet, and rocks of the character of those just noticed evidently run on in the eastern part of Mount McLean, still further north.

Cayoosh Creek, which in late years has been the scene of somewhat important placer-mining and near which veins of auriferous quartz have been found, was examined for about five miles westward from the bridge, or to the Bonanza mine. It cuts across the strike of the rocks nearly at right angles. Near the bridge and mill, the stratified rocks consist, so far as seen, of blackish and greenish quartzose schists, but they are much broken up and confused by large dykes of gray granite, which lie nearly in line with the granitic mass of Mount Brew, to the southward.

Section on
Cayoosh
Creek.

The stratified rocks appear, as seen in the end of this range nearest to the Fraser, to have a general easterly dip at low angles. They may thus be supposed to pass beneath the horizon of the serpentine and associated rocks, the strike of which along the west side of the Fraser River has already been traced. Further up the stream, opposite the first large valley from the south, the beds assume nearly vertical attitudes, but still further in the same direction, they again flatten out, and near the Bonanza mine are found to have easterly dips at moderate angles. It is not known whether the zone of nearly vertical rocks represents a compressed anticlinal or synclinal form, or whether it merely consists of a number of compressed smaller folds; but that the rocks are everywhere much plicated on a small scale, is evident from the conditions in limited sections and even in hand specimens.

The greater part of the rocks met with in the cross-section afforded by Cayoosh Creek, may be described as black or blackish argillites, often lustrous, sometimes much wrinkled and corrugated, and occasionally micaceous with very fine mica. Many of them are more or less distinctly calcareous. Near the Bonanza mine, a rather notable development of black and probably slightly graphitic argillites occurs. Inter-

Character of
rocks.

At Bonanza
mine.

bedded with these are some gray felspathic schists, which occasionally show the drawn-out forms of their original constituent particles, and have evidently, like the similar rocks of the northern part of Glen Hart (p. 87 B), and some of the Boston Bar rocks been produced by the action of pressure upon volcanic ash rocks or volcanic tuffs. Some green schists, chloritic and epidotic, are also found, as well as green rocks of the same kind not notably schistose, and still preserving the character of ordinary altered tuffs. Some of these are finely plicated and exactly like those seen at the bridge on Texas Creek (p. 93 B).

Saussurite.

In one place, not far from the east end of Seton Lake, a gray saussurite rock was collected, and at two miles and a half below the Bonanza mine, a zone several yards in thickness of greenish-gray talc-schist was observed to be interbedded with the series.*

The auriferous quartz veins which intersect these rocks are described on a later page with other occurrences of economic minerals.

Seton Lake.

For about a mile, along the lower part of Seton Lake, on the north side, rocks generally similar to those of Cayoosh Creek are found, including indurated glossy argillites and green schists, with some cherty quartzites more or less foliated, and a little greenish schistose serpentine. With these are rocks of gneissic appearance, some of which are probably foliated granite, as at a short distance further west along the lake a mass of scarcely foliated gray granite is met with.

Outlines given
to formations
in Coast
Ranges.

Respecting the outlines given to the Paleozoic rocks and the granites in the part of the Coast Ranges included by the map, it may be explained that these are based upon a certain number of traverses, shown upon the map, in conjunction with sketches and bearings obtained from several of the higher points. They can thus be assumed to possess but a general accuracy. The western edge of the main mass of granitic rocks was nowhere actually reached, but beyond it, the mountains are evidently composed of schistose rocks, and the line is approximately drawn so as to separate the two classes of mountains. It might almost be assumed that the schistose rocks on the west are of the same character with those above described, but additional certainty is given to this assumption by the fact that these rocks come out in force on the Fraser River, in the line of their strike, in the vicinity of the mouth of Salmon River, some distance beyond the south line of this map. These rocks have been examined, and it is found that they run along the part of the Fraser River referred to, as far as North Bend and a little beyond, while on the opposite side of the river

Rocks to west
of main gran-
ite axis.

* See Appendix I., Nos. 16, 17, 18, 20.

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* Report

they constitute the series which in the original report of 1871-72 was designated the Anderson River and Boston Bar series. The lithological characters and present appearance of these rocks are identical with those of most of the Palæozoic rocks here described, and there can be no reasonable doubt that their age is the same. The actual width of the belt of Palæozoic rocks in the south-western angle of the present map remains, however, indeterminate.

In order to afford a more definite idea of the Palæozoic rocks which enter into the composition of this part of the Coast Ranges, it will be advisable to add some notes on the Anderson River and Boston Bar series, above referred to, in its typical development along the Fraser River to the south of the present map. Some notice will be found of these rock in the reports for 1871-72 and 1877-78.* In the last-mentioned report, for the sake of brevity, the beds in question were generally designated merely as the Boston Bar rocks. In 1888 they were examined along the line of railway on the west side of the Fraser, where it was possible to obtain a better idea of the series as a whole than had previously been gained on the old wagon-road on the opposite side.

Boston Bar
rocks to south
of map sheet.

Speaking generally, these rocks occupy the west side of the valley from a point about three miles below the cantilever bridge to one three miles below North Bend station, a distance in all of about nineteen miles. They are separated by a mass of granite from the Cretaceous rocks seen near the cantilever bridge, this granite being the continuation of the main granitic area shown on the present map to the west of the Fraser. The strike of the rocks crosses the Fraser valley at a very oblique angle, the belt of schistose or slaty rocks being continued to the northward, after leaving the Fraser, in the Salmon River valley, and to the southward, east of the Fraser, along the Anderson River valley. The obliquity of the line of examination does not favour the definition of an exact section, and the observations do not admit any precise thickness to be given for each of the various classes of rocks, but their order and character is approximately as follows :—

Cantilever
bridge to
North Bend.

The first, and presumably the lowest rocks, seen just south of Quioieek River, are dark gray, quartzose mica-schists. About four miles further south and probably considerably higher in the series, somewhat similar, but pale gray, highly quartzose schists were next seen. These are followed by greenish, rather lustrous schists, and thin-

Order of su-
perposition.

* Reports of Progress, Geol. Surv. Can., 1871-72, p. 62; 1877-78, p. 73b.

bedded cherty quartzites with slightly micaceous, shining, black divisional planes, and by massive gray indurated sandstones, verging on quartzite, but not cherty. Overlying these beds, are dark glossy schists and quartzites. Then, after a considerable concealed interval, dark argillite-schists and schistose quartzite, the former somewhat graphitic. These rocks are seen in cuttings from a mile to two miles south of Keefer Station.

At the south end of the Salmon River bridge, graphitic argillite-schists, with talcose and quartzose schists with a bed of nearly massive gray talc, occur, the whole followed by more blackish argillite-schists.

Thickness.

Near the 134-mile post on the railway, the section is interrupted by the appearance of gray gneissic rocks, which may be regarded as probably representing a mass of foliated granite.

If, as is supposed, the above represents an ascending series, terminated above (and to the westward) by the gneissoid rocks, the thickness displayed must be between 6000 and 7000 feet, of which the greater part is made up of argillites in different stages of alteration.

Rocks near
North Bend.

Beyond the gneissoid rocks, after a concealed interval, black argillites are again found in large exposures between one and two miles above North Bend station. These are very regularly bedded and banded with thin gray layers, and with them are some gray quartzite-like sandstones. Two miles to the south of North Bend, black, shining argillite-schists, becoming chistolitic in places and interbedded with dark gray mica-schist, are exposed. In following these rocks for a short distance in the cuttings, the micaceous schists are found to become more abundant and coarser grained, resembling gneisses, while many fine-grained granitic dykes cut through the rocks, and in some instances were seen to hold included fragments of the gray schists. A little further on the usual massive gray granite reappears.

Junction with
granites.

This junction of the Boston Bar rocks with the granites, which may be observed in detail, might be assumed to show a blending and true interbedding of the argillites with gneissic rocks; but it is believed that the appearance presented is the result of ancient granitic intrusions among these rocks near the line of contact, and that the whole composite mass of granitic and stratified rocks has subsequently been subjected to great compression, such as to induce a foliated structure in the granitic material.

East side of
Fraser.

In addition to the rocks above mentioned, thin beds of gray laminated limestone, green schists, and gray felspathic schists formed from squeezed volcanic ash, were observed in certain places on the east side

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* *Op. cit.*,

of the Fraser in 1877.* The gray schists are identical in character with those noticed in the northern part of Glen Hart (p. 87 B).

Palæozoic Rocks on and near the North Thompson River.

These are believed to be separable into two great groups, of which the higher is wholly or in great part Carboniferous, and referable to the Cûche Creek formation, the lower to the Nisconlith and Adams Lake series, correlated in a general manner with the Cambrian; as elsewhere explained (p. 27 B). The nature of the provisional line of division which has been drawn on the map between the Cûche Creek and Nicola formations is also referred to on another page (p. 124 B).

Rocks of Cambrian and Carboniferous age.

In noticing the Palæozoic rocks of this vicinity, it will be convenient to begin with those assigned to the Cûche Creek formation, in order that these may be more closely compared with the rocks of the same formation, to the description of which the immediately foregoing portion of this report has been given.

Rocks referred to the Cûche Creek Formation.—An attempt has been made, along the lower part of the North Thompson, to obtain the necessary data for the construction of a section of the rocks there found and characteristic of the adjacent country on both sides of that river. The sides of the river-valley appeared to be the only place in which sufficient connected exposures of these rocks occurred to offer any prospect of such a section, although it was known that the general direction of strike is oblique to the valley, being in fact about north-north-west. The information obtained along both sides of the valley has since been combined, but with very indifferent results, in so far as the main purpose of the examination is concerned. Both strikes and dips proved to be exceedingly irregular in detail, and the rocks of the region generally are so much shattered and disturbed, that it is practically impossible to trace out single beds for any considerable distance. The diagrammatic section (No. 3), which has been drawn as an attempt to represent the structure along a part of the valley, extends from the north side of Reservation Creek, northward, to the vicinity of the granite mass which comes out on the river beyond Sullivan Creek.

Section along lower North Thompson

Section No. 3.

The general character of the rocks met with may be briefly described as follows:—Blackish or dark gray argillites preponderate in the section. These are usually shaly, flaggy or slaty, but are so much cut

General character of rocks.

* *Op. cit.*, p. 73 B.

up by jointage-planes in every direction, that they generally crumble away readily into rubbly slopes, like those seen descending from the higher parts of Paul's Peak. The argillites are very often more or less calcareous, sometimes slightly micaceous near their contact with the granitic masses, and particularly so in the vicinity of the granite near Jamieson Creek. They are frequently somewhat silicified, and then become black or grayish, fine-grained rocks like chert or hornstone, resembling the cherty quartzites of the C  che Creek formation on the Bonaparte River and elsewhere to the westward. With the argillites, hard grauwacke sandstones are in many places found to be interbedded. These are generally of paler colours than the adjacent argillites, and pass, in several places, into beds of fine-grained conglomerate or breccia, of which the constituents are rather varied, but which often hold black and gray slaty or schistose fragments, which may have been derived from Cambrian strata, like those seen in the section above Fish-trap Rapid (p. 107 B). The conglomerates have in some places become highly silicified, and have been so much squeezed that their pebbles are flattened out parallel to a common plane.

Limestone
beds.

In addition to these rocks, the section comprises at least two beds of limestone, and considerable bodies of greenstone of contemporaneous origin and not infrequently of the character of a diabase-agglomerate. The higher of the two beds of limestone, appears to have a thickness of 100 to 200 feet, while the lower is much thicker. The lower limestone is immediately overlain by a bed of conglomerate of the kind already described, the association being apparently rather constant, as it was observed in several localities. This limestone is the lowest rock clearly recognized in the section, and the upper limestone is probably about 2000 feet above it, the intervening rocks being for the most part argillites, &c., as already described. Above the upper limestone, diabase and similar volcanic intercalations are more abundant, constituting a great part of this portion of the series.

Thickness.

The whole thickness of beds seen on this part of the North Thompson appears to be about 7500 feet.

The tracing out in detail of the limestone beds contained in this series of rocks, appears to offer the only method of obtaining more exact knowledge of their stratigraphy and thickness, and the age assigned to the whole series depends chiefly upon that indicated by the fossils contained in the associated limestones, a reference which appears to be justified by the interrelation of the various component members of the series, as well as by their resemblance to the rocks already described to the eastward.

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The best exposure of the limestone bed, above designated as the lower Outcrop of limestone, is found on the west bank of the North Thompson near Venn's, almost directly opposite the mouth of Sullivan Creek. The dip of the limestone is generally eastward, but just at this place the direction of its strike appears to change. It has been followed in a north-north-west direction along the higher slopes of the valley for about three miles. To the southward, it turns more to the west, and possibly abuts against the granite mass found near Jamieson Creek. The outcrop near Venn's is probably the best and most accessible source of lime for burning to be found along this part of the river.

On the opposite side of the river, a mile north of Sullivan Creek, and almost in contact with the edge of the granite there, exposures of the upper limestone are seen. These run northward parallel with the main direction of the last-described band, crossing the river, and are again seen on the west side of the river two miles and a half further northward. In both cases the dips are to the eastward.

Another outcrop, believed to be of the upper limestone, is found a mile and three-quarters south of Edwards Creek, on the east side of the river; and between three and four and a half miles further south, on the same side of the river, several exposures referred to the same upper limestone band occur.

Still another prominent outcrop of limestone appears to the east of the North Thompson valley, in the Inner Valley, five miles due south from the upper part of Edwards Creek. This may probably be the lower band, and is again undoubtedly the same with the limestone seen in extensive exposures in hills to the north of the South Thompson, about ten miles east of Kamloops, a short distance beyond the east edge of the present map. The limestone of the Inner Valley is almost entirely composed of crinoidal fragments, and large round crinoidal columns more than an inch in diameter occur in it, but nothing more characteristic in regard to its age was observed. In the case of the limestone on the South Thompson with which it is correlated, the evidence of Carboniferous age is decisive. The abundant occurrence of *Fusulina* in it is noted in the report for 1877-78, (p. 80 B) where it is stated that the mass of the rock is made up of crinoidal debris and fragments of small corals. Imperfect remains of brachiopods were also found, including a *Rhynchonella* and a shell which may be *Hemipronites crenistria*. Since that time some beds have been found to be almost composed of large pear-shaped foraminifera referable to *Saccamina Carteri*, Brady, a form which in Scotland occurs both in the Fossiliferous limestone.

Lower and Upper Carboniferous limestones. A *Valvulina* was also observed, closely resembling *V. palæotrochus*, Ehrenberg.

Rocks of
Paul's Peak.

The greater part of Paul's Peak, and of the high ridge running eastward from it to the edge of the map, consists of hard, splintery and sometimes cherty, dark argillites, with grauwacke-like quartzites and occasional greenstone or felsite beds.* These rocks represent the continuation of those described in the southern part of the section along the North Thompson, in the strike of which they lie.

Similar rocks again occur in the opposite hills, to the east of Kamloops, on the south side of the South Thompson.

Rocks of
Garde Lafferty.

The eastern part of the tract of country named the Garde Lafferty, approximately from a line drawn through the long lake with lines in its centre, is again occupied chiefly by rocks resembling those of the lower part of the section on the North Thompson. They consist, like these, of argillites, grauwackes, and some beds of fragmental diabase rocks. The characteristic black cherty beds are also well represented. These rocks scarcely show any development of mica on their bedding planes, but they are often much shattered, disturbed and jointed in all directions.

Dolomitic
veins.

In following the hills which face toward Kamloops, on the south side of this tract, these rocks are in one place, for a width of nearly a mile, not only excessively shattered, but also highly charged with silica, dolomite and iron pyrites, and traversed by veins of more or less siliceous dolomite. The red and yellow colours of the hill-sides due to the disintegration of this band of rocks are visible from afar. The change has evidently been produced by solfataric action proceeding along a system of fractures, which here runs in a north-westerly direction. The same solutions, issuing through these older rocks, have doubtless caused the dolomitization observed in some of the lower parts of the Tertiary in this vicinity (see p. 163 B).

Doubt attach-
ing to North
Thompson
section.

Reverting to the section along the North Thompson, first described under the present heading, it is proper to explain that much doubt still attaches to it. The existence of considerable faulting parallel or nearly parallel to the line of the valley is suspected, and it is probable that a line of this kind separates the C  che Creek rocks from those of the Cambrian in the vicinity of Fish-trap Rapid. Some facts noted in the course of a detailed examination along the valley south of Sullivan Creek, led to the belief that two distinct series of rocks may co-exist there, in which cases it is possible that beds of the Nicola

*Appendix I., No. 19.

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formation may be represented as well as those referable to the C  che Creek. This appearance may, however, be due merely to two superposed systems of folding, and meanwhile, the evidence as it stands, favours the inclusion of the whole of the beds in the C  che Creek formation.

About the head of Watching Creek, and on the thickly wooded plateau for some miles to the east of its valley, rocks evidently representing those of the lower part of the North Thompson, were again observed. The principal direction of strike is here about north-east by south-west, while the varying dips indicate that these rocks form a series of folds. The materials are principally argillites, not notably altered, though indurated, and seldom at all schistose in character. They are often very finely bedded, and not infrequently more or less calcareous. With these are interbedded some grauwacke sandstones and conglomerates, as well as beds of altered volcanic material, some of which are evidently fragmental in character. These are seldom notably green in colour, and one of them, microscopically examined, appears to be a diabase-porphyrite.* Bands of blackish limestone were also noted in some places, interbedded with the argillites.

Rocks near
Watching
Creek.

Cambrian Rocks near Fish-trap Rapid.

Between the mouths of Whitewood Creek and Louis Creek the North Thompson assumes a north-east and south-west trend, cutting across the strike of the rocks nearly at right angles, and affording the most satisfactory section of the Cambrian rocks met with in the area of the Kamloops sheet. Much of this part of the valley is narrow, and the rocks are fairly well exposed in it. The section as presented (No. 2) runs from the vicinity of Fish-trap Rapid to the lower part of Louis Creek, about six miles, and thence northerly to the vicinity of the Barri  re River, about three miles further. The observations upon which it is based were made, for the first part of this distance, along the south-east side of the North Thompson and along the valley of Louis Creek for some miles above its mouth. For the second part, chiefly in the hills to the east of the North Thompson a couple of miles back from the river.

Section No. 2.
Fish-trap
Rapid.

The oldest rocks found appear in the form of a somewhat contorted anticline, of which the axis seems to slope down to the north-westward. These are referable to the Nisconlith series and consist of hard black argillites and argillite-schists, often rather lustrous from

Central anti-
cline.

*Appendix I., No. 6.

the development of minute mica crystals, and passing from these in some places into well characterized black micaceous schists. These black schists do not appear to be calcareous. The thickness represented is about 3100 feet, but the base of the series is not seen. The highest beds appear to blend with the rocks of the next overlying series, which consists chiefly of greenish and gray schistose rocks resulting from the dynamic metamorphism of diabases and diabase agglomerates and representing the Adams Lake series, or a part of it, with an estimated thickness of 9500 feet.

Rocks to
south-west.

In the syncline at the south-west end of the section, about 6000 feet of the lower part of these rocks is seen. They are here less altered than those on the opposite side of the main anticline, and are clearly recognizable as ordinary green altered diabases, or greenstones, becoming more or less schistose in structure, but in some places still showing an original agglomeritic character. The prevalent colours throughout are greens and gray-greens.

Rocks to
north-east.

On the north-east side of the anticline of Nisconlith rocks, the Adams Lake series recurs in the manner shown in the section. Its rocks here have suffered greater metamorphism and are chiefly represented by gray or greenish-gray often lustrous schists, with, in their upper part (and at a horizon higher than any represented in the first syncline) some rather considerable intercalations of blackish argillite-schists. The highest beds seen, in the centre of the north-eastern syncline, consist largely of quartzose schists, with quartzose and arkose conglomerates, more or less schistose, glossy gray or nearly white schists and some black argillite-schists. These have a thickness of about 2000 feet, in addition to that already stated for the lower part of the Adams Lake series.

North of Bar-
rière River.

The exposures found on the lower part of the Barrière River, and along the east side of the North Thompson northward from that river, are insufficient to admit of the further continuation of this section, but it is believed that the greenish and bluish-gray altered diabases and felspathic rocks chiefly seen there, are also referable to the Adams Lake series, forming a still higher part of it and one which has escaped much of the dynamic change by which the beds above described have been affected. It is also probable, that the main strike of these beds here runs nearly parallel to the North Thompson valley, though the massive character of the rocks renders it very difficult to determine this.

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Rocks assigned to the Cambrian, South of Fish-trap Rapid.

The rocks in the hills to the east of the North Thompson, south of the Fish-trap Rapid section, have not been sufficiently examined to warrant any detailed description of them. It has been endeavoured to draw an approximate line between the Cambrian rocks and those referable to the Carboniferous, but this depends almost entirely on the lithological characters of the rocks, without any exact knowledge of the relations of the two series along their supposed line of contact. It is, however, very probable that this line is a faulted one, due to one or more faults which may nearly follow the general line of the North Thompson valley.

Between Sullivan and Edwards Creeks, and to the south of Edwards Creek, near the east border of the map, the rocks believed to be Cambrian consist largely of greenish, diabase-like materials in various stages of alteration, often schistose, and passing over into coarsely micaceous schists of almost gneissic aspect. These last are, however, almost in contact with one of the granite masses with which the structure of this region is complicated, and may owe their excessive alteration in part to that circumstance. With the above-mentioned rocks some hard, micaceous argillites occur, and white banded quartzite was also noted. A bed of highly crystalline limestone is also seen in a couple of places, where it appears nearly to coincide with the line between the argillites, referred to the Nisconlith, and the green schists, referred to the Adams Lake series, although no limestone was observed in a similar relation in the Fish-trap Rapid sections.

Between the south side of the Sullivan Creek granitic mass and Island Pond, near the edge of the sheet and beyond it, there is a considerable development of schistose argillites, much broken, but probably representing an irregular anticlinal elevation, which may be connected with the intrusion of the granitoid mass.

Rocks of the Plateau to the North of Whitewood Creek.

To the north of Whitewood Creek and west of the North Thompson, a belt of plateau country averaging about six miles in width, is occupied by rocks of which the stratigraphical position is very doubtful. It must be explained that this region of country is exceedingly rough and difficult to traverse, by reason of its wooded and broken surface, and that but a few exploratory lines have been carried through it.

Rocks as-
signed to
Cambrian.

The trail which runs westward from the North Thompson to Bonaparte Lake, leaves the valley of the river about six miles above the mouth of the Barrière, and some three miles below the village on the Indian reservation. On this trail, near the foot of the steeply sloping side of the valley, and about 430 feet above the river, some brecciated gray limestone was first found, after which many fragments of dark argillites were observed, though not seen in place; but in the main, for a distance of about three miles, green, slightly schistose, altered diabases appear to be characteristic. These rocks are believed to form a continuation of those of similar character seen in the section near Fish-trap Rapid, and they are provisionally assigned to the Cambrian.

Rocks as-
signed to
Câche Creek.

In following the trail westward from the point last indicated, a great series of dark-coloured and often nearly black schistose rocks is met with, which continues all the way to the edge of the granites on Eating Lake, or for a distance of eight miles and a half. The strike of these rocks, wherever observed, is not far from north-and-south, and the dips along the line mentioned appear to be uniformly westward, at low angles near the edges of the diabase series, but elsewhere probably averaging about 60°. The appearances thus indicate that these schists overlie the diabases, and if it be supposed that they form a continuous ascending series this would have a thickness of over 18,000 feet. It is, however, much more probable that folds or faults not recognized have to be allowed for, and that there is much repetition of beds, though their actual volume must in any case be very considerable.

Their charac-
ter.

Lithologically, these beds consist of argillites, schistose or slaty, more or less distinctly micaceous and approaching in character to phyllites, and of fine-grained black or blackish rocks containing a larger proportion of bisilicate minerals, very much decomposed and altered and probably representing beds which have originally been volcanic in their origin. With these are occasional beds of hard fine-grained gray quartzite or grauwacke.

The appearance of these rocks alone does not enable it to be decided to what series they should be referred. They very closely resemble some of the strata common in the Cambrian, but they are equally comparable with the more highly altered beds of the Câche Creek formation, and are in some cases lithologically indistinguishable from strata described under the name of the Campbell Creek beds. The apparent absence of limestones constitutes a point of difference between them and the strata referred to the Câche Creek on the lower part of

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the North Thompson, but this may depend merely upon the incomplete character of the examination made.

Southward, from Eating Lake to Poison Hill, following a little to the east of the main edge of the basaltic and granitic rocks, similar micaceous argillites and fine, black, micaceous schists are the predominant rocks, but the directions of strike and dip are less uniform. Near the head of Skull Creek, where that stream was crossed on the route indicated on the map, these rocks are singularly contorted, being affected, besides their main flexures, by close parallel folding in undulations from a few inches to a few feet in diameter. They are also here traversed by numerous small quartz veins, which show a tendency to follow the contorted bedding-planes and are characterized by parallel marks of shearing, which indicate compression acting in a direction of N. 40° E. or the reverse.

Continuation
southward.

The isolated area of old rocks shown to exist to the west of Skoatl Point, is so much covered by drift that its composition was very imperfectly ascertained. It appears, however, to consist chiefly of gray-green porphyritic diabase, much altered, and is provisionally referred to the Nicola series.

Near Skoatl
Point.

Two miles south-east of Poison Hill, the micaceous argillites were found to be interbedded with gray-green diabase-porphyrates,* in a manner precisely analogous to that observed on Campbell Creek (p. 123 B), and it is probable that the horizon is about the same in both cases. Quartz veins were noticed to be abundant here, but specimens of them subjected to assay proved to contain nothing of value.

Near Poison
Hill.

Similar micaceous argillites, with some diabase, apparently interbedded, were found to characterize the tract of country, some miles to the south-westward, in which the basalts have been cut through and in which Caribou Lake lies. The general direction of strike in all this region is north-west by south-east, and in the vicinity of Caribou Lake quartz veins were again noted to be abundant.

At Caribou
Lake.

It will be understood, from the brief description thus given of a tract of country some seventeen miles in length with an average width of about six miles, that our knowledge of its geological structure is yet very imperfect. It is quite possible that the dark schistose rocks above described may eventually be found to belong to the Cambrian, and to represent an extension of the Nisconlith series. In that case a line of separation would require to be drawn between them and the rocks of

Age uncertain.

*Appendix I, No. 5.

the lower North Thompson, and it is probable that such a line might be found to run from the vicinity of the mouth of Whitewood Creek to Basalt Point of the map.

TRIASSIC ROCKS, AND SECTIONS ILLUSTRATING THE NICOLA FORMATION.

Section South of the Ashcroft Cretaceous Area.

Examination
of the section.

A notice of the rocks referred as a whole to the Triassic, under the name of the Nicola formation, may be begun by a short description of the section found along the east side of the Thompson, south of the Ashcroft Cretaceous area. This section was partially examined in 1877, and in 1888 some additional observations were made on it along the line of the railway, but the results obtained remained fragmentary. After all other parts of the area of the Kamloops map-sheet had been gone over, the unusual regularity of the rocks at this place seemed to render it desirable that they should again be examined, and two days were in consequence devoted to this in July, 1894. The section was found to be not so regular as had been anticipated, in consequence of the protrusion into it of several masses of the granitic rocks of the vicinity; but the effect of these has been eliminated as far as possible, and there can be little doubt that the general order and composition of the series is now fairly well understood.

Fossiliferous
beds.

The discovery of fossils at two different horizons has also added materially to the value of the section as a whole. Professor A. Hyatt has been so kind as to make a preliminary examination of these and a comparison of them with some of the collections lately obtained by him from Californian localities, the results of which are of great interest. He finds in effect that the fossils collected from the lower of the two horizons are undoubtedly Triassic, comprising a *Daonella* like *D. Lommeli*, a shell resembling *Panopea* (?) *Remondi*, Gabb, and a small ammonoid. Those of the upper horizon are probably Jurassic. This horizon is actually separated from the lower by about 12,300 feet of strata. The fossils found in it include *Lima parva*, Hyatt MS., *Entolium* like *E. equabilis*, Hyatt MS., *Pecten* like *P. acutiplicatus*, Gabb, and two species of *Rhynchonella*, one like *R. gnathophora*.

General lie of
the strata.

The exposures which afford practically the whole of the measured section, occur on the east side of the Thompson Valley and in the adjacent hills in a distance of about four miles southward from the end of the Cretaceous area. The general dip is nearly north, or at right angles to the valley, the angles of inclination varying from about 15° to 50°. No evidence of important faulting was found, and it was possible to observe the angles of dip in many places, notwithstanding the generally massive character and originally volcanic origin of a large part of the

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constituent rocks. The highest rock seen is a limestone, in small exposures in the hills about two miles south-east of the railway at Black Cañon. It is overlapped there by coarse basal conglomerates and breccias of the Cretaceous, consisting chiefly of granitic fragments with a calcareous cement. These exposures are somewhat removed from the main line of section, and are complicated by the occurrence of a small granitic boss, but there is little reason to doubt that the rocks seen in them are conformable with those included under No. 2, of the section. The lowest member of the section is that numbered 9. It occurs about two miles north of Spatsum station, where it is cut off by a projecting mass of granite, beyond which the regularity of the series becomes disturbed and the order of superposition doubtful. All the beds included in the section are believed to appertain to the Nicola series. The section obtained may be summarized as follows, in descending order :—

Section south
of Ashcroft.

	Feet.
(1.) Gray limestone, of which at least 20 feet was seen. It often contains numerous small angular fragments of siliceous rocks and is fetid, when struck. Contains fossils believed to be Lower Jurassic.....	20
(2.) Chiefly bluish and gray or greenish-gray fine-grained felsite or petrosilex, apparently passing into fine-grained decomposed diabases. Some agglomerate, composed of similar materials, is included in this part of the section, but nearly all the rocks break with a homogeneous sub-conoidal fracture.....	1,800
(3.) Chiefly purplish and gray rather fine-grained agglomerates, occasionally greenish and often with spots of epidote.....	1,300
(4.) This part of the section is represented by few exposures, but appears to consist chiefly of bluish and greenish-gray fine-grained felsites, occasionally somewhat porphyritic.....	2,000
(5.) Chiefly agglomerates, which are often fine-grained and pass into moderately well bedded grauwaacke or arkose sandstones, generally indurated and often calcareous. Usual colour grayish. With these are associated (particularly toward the base) blackish argillite-like rocks and some thin beds of limestone and of fine felsite-like rocks.....	2,000
(6.) The upper half of this member of the section is composed of gray felsites with interbedded limestones, of which the thickest observed is about 20 feet. Lower half not exposed.....	1,550
(7.) Chiefly green diabase-agglomerates, often coarse.....	2,100
(8.) Chiefly green rather fine-grained diabase-agglomerates with interbedded blue-gray limestones. In one cliff showing about 500 feet of beds, one-third of the whole appeared to be limestone. The limestones are best developed in the upper part of this division and Triassic fossils were found about the middle.....	1,300
(9.) Chiefly gray and blackish fine-grained felsites.....	539
Total.....	13,590

It is very probable that another limestone bed of considerable thickness underlies the last-mentioned member of the section, but the strata become too much disturbed to enable this to be certainly determined.

General com-
position of the
series.

In explanation of the above summary, it must be added that the subdivisions adopted in describing the section are somewhat arbitrary, there being no very marked distinctions of a natural kind between its several parts, which show on the contrary, throughout, much blending and interlocking. In a general way it may, however, be noted, that the lowest beds recognized are fine-grained, generally dark-coloured felspathic materials; that above these, and constituting the greater part of the lower half of the section, green diabase and diabase-conglomerates occur, and that with these most of the limestones are associated. That fine-grained, gray agglomerates or tuffs characterize the middle of the section; that the entire upper part of the section shows chiefly fine-grained diabases and felsites with some agglomerates, which are here often purplish. The last-mentioned part of the section contains little or no limestone until the highest bed (No. 1) is reached. The thickness of this bed was not definitely determined, but is probably not great.

Rocks near
Spatsum.

The rocks included under division No. 2 of the section, were imperfectly seen in 1877, and were then supposed to form a part of the Cretaceous series, * an opinion which now appears to be definitely disproved. It will be noted that their lithological character is practically identical with that of the rocks now known to form the apparently highest part of the Nicola series near Nicola Lake (p. 136 B). The same rocks occupy a small tract to the east of the southern part of the Ashcroft Cretaceous area.

At Great
Rock-slide.

To the south of the section just described, after an interruption caused by a granitic intrusion, another isolated mass of rocks which is referred to the Nicola formation appears. This includes green diabase with some limestone, and extends as far as Spatsum station. Beyond this, the narrow selva of rocks between the Thompson and the edge of the granite, is believed to be referable to the C  che Creek formation, with the exception of a patch occurring on the hill from which the Great Rock-slide descends. The upper part of this hill appears to be entirely composed of a peculiar breccia or agglomerate, much silicified, and holding numerous fragments of limestone. Some of the fragments of limestone and greenstone, or other felspathic rock, are nearly a yard in diameter. Where least altered this limestone is dark gray in colour, but it is often changed into a white marble, while other pieces show concentric zones of alteration on the outside, with a nucleus of little changed limestone. Crystals of iron pyrites are abundantly disseminated through the breccia while copper-staining is often notable in the crevices and joints. Great blocks of the breccia

*Report of Progress, Geol. Surv. Can., 1877-78, p. 112 B.

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ated rocks, which in falling have bounded clear of the general slope, strew the terraces along the foot of the slide.

The great size of the constituent fragments of this breccia seem to show that it must have been formed at or very near to a centre of volcanic eruption, and this eruption, it is supposed must have occurred during the deposition of the Nicola formation, to which the breccia itself is referred.

It is believed that the Thompson, in this part of its length, coincides with the line of a fault, which is accompanied by much comminuted fracturing and crushing of the rocks in its vicinity. This faulting is probably in relation to the general run of the edge of the granite, and may possibly have occurred at the time of its intrusion. In any case, the rocks on the west side of the river are crushed, reddened, silicified and decomposed in a remarkable manner, elsewhere described (p. 80 B). No distinct connection can be traced between them and those on the east side of the river. They are referred as a whole to the C  che Creek formation, but may very possibly include broken remnants of parts of the Nicola formation as well.

Great line of fracture.

In the hill above the old 89-mile stable, however, considerable exposures of limestone occur, in which fossils have been found, these Professor Hyatt refers to the same age as those of the highest bed of the section last described, or Lower Jurassic. These limestones further resemble that bed in character, and like it are charged with angular fragments of siliceous rocks. They are much broken up, and although associated with some greenish schistose rocks and with a gray spotted elastic felsitic or halfeint rock, it is not certain that these are actually related to the limestone. The probable area of the newer rocks is indicated on the map. It may be added, that a couple of miles above the 89-mile stable, on the road, another limestone occurs in which Mr. Richardson collected a few fossils evidently referable to the C  che Creek formation, Mr. Billings having determined them as of an age between the "base of the Devonian and summit of the Permian."*

Exposures near 89-mile stable.

The fossils from the limestones near the 89-mile stable are described by Professor Hyatt as including a *Terebratula*, two species of *Entolium* and a *Pecten*, all closely resembling forms found by him in beds of Lower Jurassic age at Taylorville, California.

Fossils.

Section along the Thompson Valley from Bonaparte River to Copper Creek.

An examination along the line followed by this section appeared to be particularly important, as it constitutes the only direct link of con-

Section No. 1.

*Report of Progress, Geol. Surv. Can., 1871-72, pp. 61-62.

nction between the older rocks of the western and eastern parts of the map-sheet. Elsewhere these two areas are separated by wide masses of granite or by Tertiary volcanic formations. A satisfactory connecting section along this line would have been all the more valuable because of the considerable lithological differences found between the C  che Creek and Nicola rocks of the two sides of the Kamloops sheet, but although examined with some care, and on several occasions, the section afforded has proved to be by no means a satisfactory one. The stratified rocks are broken up by large intrusive masses of a granitoid character, and, being for the most part old volcanic materials and much shattered, they do not supply the necessary data for working out the evidently somewhat complex structure. The section as presented (Sect. No. 1) must therefore be regarded as little more than a diagram, representing what is believed from the examinations made, to be the most probable arrangement of the older rocks. It affords a means of describing in outline the character of the rocks met with on both sides of the Thompson, and of bringing together the results of traverses made along the wagon-road and the railway line, as well as those of other traverses through the adjacent hills.

Line followed
by the sec-
tion.

The line of section approximately coincides with the east-and-west part of the Thompson Valley, running from its tributary the Bonaparte to Copper Creek, Kamloops Lake. It is to the wide and deep erosion of this great valley that the removal of the overlying Tertiary rocks is locally due. The actual length of the line of section upon which the observations have been projected, is about twenty-three miles, from end to end; but as drawn it is a couple of miles longer, because of the four distinct courses which it had been found best to follow in laying down the line upon the map. The line thus runs from a point on the Bonaparte River just south of the minute outlier of Tertiary rocks there, in a bearing N. 79   E., to a point on the wagon-road about a mile beyond the crossing of Eight-mile Creek. Thence, in a direction S. 70   E. to the Deadman River, near the bridge, approximately following the wagon-road. Thence in a bearing of N. 35   E. to the summit of the southern spur of the plateau, due north of Savona. Thence N. 68   E. to Copper Creek, which it reaches at a distance of about two miles from its mouth. The approximate contour of the surface is indicated by the upper line of the section, the horizontal and vertical scales of which are identical.

West end of
section.

The section at its western end, where it leaves the Bonaparte River, shows the junction of the C  che Creek rocks with those of the Cretaceous. The line of junction can be clearly seen along this part of the

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Bonaparte. The older rocks are at angles of 60° to vertical, and here consist of greenish or gray felspathic or diabase schists, with serpentine in considerable mass, and probably forming a bed in the series, as this rock is often found to do elsewhere in this part of the region. The Cretaceous rocks in contact with these, consist of greenish and bluish sandstones, which pass into coarse rough grits composed of heterogeneous fragments, and all much hardened. These also, so far as could be ascertained, stand at very high angles. It is probable that faulting accompanies the junction of the two formations, as represented on the section, but quite possible that the Cretaceous rocks here merely represent the western and overturned limit of a syncline.

The Cretaceous rocks of the area crossed by the section are elsewhere described in greater detail (p. 154 B). The dips given to them in the section, embody the observations made in the vicinity but not all upon the line of the section, and it is impossible with the information gained to show the actual folds or faults by which this area of the Cretaceous may be affected. The general westward dip, at angles of 40° to 45° , of a great part of the series in this vicinity, is, however, very clearly seen in distant views of the north end of the wide ridge which occurs to the south-west of the lower few miles of the Bonaparte.

The hill crossed by the section in the middle of the Cretaceous area, is capped by nearly 200 feet of black columnar basalt, of which the individual columns were observed by Mr. McEvoy to have an annular concretionary structure. Basalt capping.

A small wedge-like area of Nicola rocks, represented somewhat diagrammatically upon the section as intervening between the eastern edge of the Cretaceous and the large intrusive mass next met with, indicates the position of an isolated area of these rocks which occupies several square miles on both sides of the river, south of the wagon-road and near the lower part of Barnes Creek. These rocks consist of greenish, grayish, blackish and often purplish fine-grained diabases and felsite-like materials, which particularly on the north side of the river, are often agglomerates. The gray and blackish felsite-like rocks frequently become porphyritic with small white feldspar crystals. No limestone was seen, and very little of the ordinary coarse green diabase. The beds as a whole evidently represent part of the upper half of the Nicola series as shown in the general section to the south of the Ashcroft Cretaceous area (p. 113 B). So far as can be made out, they dip westward, passing beneath the Cretaceous at rather low angles of inclination. Their junction with the granitoid rocks to the eastward is hard to define, particularly to the south of the river, where detached areas of the Area of Nicola rocks.

Junction with granite

old volcanic materials appear to be included in the intrusive mass and to have been in process of incorporation with it by fusion. The character of the intrusive material is itself changed by this circumstance, but a couple of miles to the eastward it becomes an ordinary mica-diorite.

Reverting to the actual line of section, on the wagon-road, where the Cretaceous is directly followed by the intrusive mass, the latter shows similar evidence of having absorbed neighbouring parts of rock of the Nicola formation. It is not homogeneous, varying considerably both in colour and texture, although generally dark greenish or greenish-gray and usually fine grained. A microscopical examination shows it to be a porphyritic diabase, much resembling some forms of the rocks of Cherry and Battle Bluffs on Kamloops Lake.*

Tertiary volcanic rocks crossing section.

The area of Miocene volcanic rocks next met with, evidently occupies an old pre-Tertiary depression which here crosses the line of the Thompson River. The volcanic rocks have a width of about a mile in their narrowest part, at the river, and serve to unite the large regions characterized by similar rocks to the north and south of this portion of the Thompson Valley. Further to the westward, the same rocks form a bold escarpment along the north side of Semlin Valley and their western outcrop, to the south of the Thompson, is also very abrupt and rugged. On the east side, they are found to overlap a granitoid diorite at the mouth of Eight-mile Creek, at a height of about 250 feet above the river. The lowest volcanic rock here seen is a coarse basaltic breccia. Effusive basalt is elsewhere developed, as well as gray tuffaceous rocks, which in some places become almost porcelaneous in character, reddish porous rocks, probably melaphyre, charged with zeolitic matter, and some pale augite-porphyrity. It is possible that sedimentary materials, such as ordinary sandstones or conglomerates, may occur in the bottom of the old depression here occupied by volcanic rocks, but none such were actually seen.

Character of eruptive masses.

The area occupied by the eruptive mass next shown, to the east of the Tertiary belt, near Eight-mile Creek, has not been very accurately determined, particularly to the south of the river, where few exposures are seen. It consists chiefly of a green-gray mica-diorite. The next, and last, eruptive mass of importance, which breaks through the section about midway between Eight-mile Creek and the Deadman, may be mentioned at the same time. It is chiefly represented by dark gray-green, much decomposed, dioritic and gabbro-like rocks, some of which are not unlike those of the last. It resembles generally the granit-

*Appendix I., No. 84.

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oid materials elsewhere found in the region, where near a contact with the stratified rocks, and on the east side of the mass, near the road, it includes a considerable quantity of diabase or similar material, derived from the stratified series. On the same side, in the hills to the north, however, considerable exposures of a bright red hornblende-granite were found. This is so different in character from the rest, that it probably represents another intrusion of different age, although its outlines were not separately traced out. It is too much shattered to be of any value for purposes of construction.

While the stratified rocks seen between Eight-mile Creek and the Deadman River are almost entirely of volcanic origin, several broken outcrops of limestone have now been ascertained to exist in this part of the section. None of these can be traced far, and it is not certain whether there is one bed of limestone or two. Most of the associated volcanic rocks are very massive in character, and are, besides, even more than usually shattered and disturbed. It is thus almost impossible to ascertain the lie of the rocks from direct observation, but there are certain differences of texture and colour moderately constant along some zones, which, taken in connection with the limestone outcrops, afford a slight clue to the structure, and upon these the hypothetical attitudes given to the beds in the section are based.

It is unnecessary to describe the rocks themselves in detail. They consist in the main of different varieties of greenish, blackish and gray diabases, sometimes fine-grained and resembling felsites. Agglomerates are common and in these purplish tints are often observable, while in some cases included fragments of limestone are abundant. Some of the agglomerates also pass into fine tuffaceous materials. Purplish grauwacke-like beds of this kind constitute a somewhat notable feature. One of the freshest and most characteristic of them, collected one mile east of Penny station on the railway, has been subjected to microscopical examination with the result elsewhere detailed.* No distinctive fossils could be found in any of the limestones, although in the limestone outcrops near the road, about four miles west of the Deadman, organic fragments are common, and a peculiar structure of oolitic aspect was observed under the microscope. This particular outcrop was at first supposed to represent part of an unconformably underlying series of rocks. It is followed on both sides by purplish agglomerate full of limestone fragments. Its resemblance to the limestone on the Deadman, however, appears to show that it must be

Nicola's rocks,
8-mile Creek
to Deadman.

Diabases and
limestones.

*Appendix I, No. 35. Compare also Nos. 32 and 29, from the north side of Kam-cope Lake.

regarded, like that limestone, as a part of the Nicola formation, and that it occurs here in the form of a sharp anticlinal, as represented on the section.

Apparent
junction with
Câche Creek
rocks.

Another point of interest in this part of the section, is found on the wagon-road, nearly three miles east of Eight-mile Creek, where the road approaches a northerly bend of the river and is protected by dry stone walling both above and below. At this place, there is pretty distinct evidence of the unconformable superposition of rocks of the Nicola series upon a projecting boss of older rocks. The lower rocks consist of greenish to nearly white granular quartzite, extremely shattered and almost porcelaneous at its junction with the overlying rock, which evidently represents an old lava-flow and is a hard, brittle, bluish-black, felspathic material.

The whole exposed mass of the lower formation is small, but an attempt was made to trace it upon the south side of the valley, where some shattered and whitened rocks of an originally volcanic nature were in effect found to occur. It is impossible to be certain of the relations of these to the surrounding Nicola rocks, but they have been indicated on the map, with doubt, as representing a part of the Câche Creek formation.

Remarkable
dyke.

The rocks at the first-mentioned locality, on the road, are cut by a dyke of very peculiar composition and appearance, which is probably of Tertiary age. This is described by Dr. F. D. Adams in the appendix.*

Relation to
section near
Ashcroft.

Taken as a whole, there can I believe be little doubt, that the Nicola rocks seen along the Thompson between Eight-mile Creek and the Deadman, correspond with some of those of the lower half of the general section south of Ashcroft (p. 113 B).

Limestones
and argillites,
Deadman
River.

Near the bridge by which the wagon-road crosses the Deadman River, on the east side of the river, are somewhat extensive exposures of limestone and argillite, with associated volcanic rocks which are believed again to represent those just referred to. The limestones are gray and fine-grained, while the associated argillites are often highly calcareous. The thickness of the limestones and argillites together appears to reach several hundred feet, but both the direction and amount of the dip is irregular, varying from N. 10° W. to N. 6° E. and from an angle of 20° to one of 45°. Both the limestones and argillites contain obscure fossils, among which portions of the guard of a Belemnite, with the remains of two species of Pelecypoda were recog-

* See Appendix I.

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nized. The limestones are overlain by a pale felspathic rock, which weathers to a reddish colour, and which, though much shattered, seems undoubtedly to form a part of the same series with the limestones. The limestone here seen, is believed to be the same with one found some five miles up the Deadman, near the Indian village, which there dips eastward at an angle of 20°.

In order to ascertain what rocks follow the limestone in ascending order, a traverse was made from the bridge at the Deadman across the area of rough hills between that river and Copper Creek. The rocks met with on this traverse are represented in the eastern part of the section to which this description relates. Briefly characterized, these rocks consist chiefly of altered diabases, sometimes apparently compact, but often in the form of agglomerates, and generally greenish or greenish-gray in colour. At a height of about 1800 feet above the Deadman, a small patch of brown basalt occurs. The area of this is somewhat uncertain, but it undoubtedly forms a mere remnant of a more extensive flow, adhering to the surface.

Rocks between Deadman and Copper Creek.

Two miles and a half from the Deadman, on this line of traverse, a zone of hard highly calcareous argillites with some grauwacke-like sandstones was found. This is repeated at a further distance of about three-quarters of a mile, the interval being occupied by diabase agglomerates containing some calcareous fragments. The dips of both outcrops of these argillites are very high, but there can be little doubt that they represent a somewhat compressed syncline. These beds contain a few fossils, among which Prof. A. Hyatt recognizes *Trigonodus*, a *Cardita* and a *Daonella* like *D. Lommeli* and apparently the same with one found in the general section south of Ashcroft, the assemblage being clearly of Triassic age.

Fossiliferous argillites.

In this part of the section, the only dips actually determined are those of the limestone at Deadman River and those of the argillites near the summit of the hills. The intervening indications of dip are therefore conjectural, but the return of the limestone on the east side of the syncline appears to be indicated by the facts detailed in connection with the section along Kamloops Lake (Sect. No. 5), which in part runs parallel to this one. The conglomerates at the base of the Tertiary, represented at the east end of this section, are the Coldwater conglomerates described in the Kamloops Lake section just referred to. They appear to be immediately followed by an overflow of igneous rock rich in olivine, probably a picrite-porphyrity, which seems to be the lowest of the Tertiary igneous materials in this neighbourhood.

Eastern end of section.

Thickness.

The information so far gained on the stratigraphical arrangement of the rocks referred to the Nicola formation in this section, is obviously too incomplete to afford any definite idea of their sequence or thickness, although there would appear to be a volume of at least 5000 feet between the limestone of the Deadman and the fossiliferous argillites.

Section on Campbell Creek.

Campbell
Creek section.

The older stratified rocks found to the south of Kamloops and the South Thompson River, are, for the most part, believed to represent the Nicola formation, but some considerable areas have been separated from these and referred to the C  che Creek formation. The grounds upon which this admittedly provisional separation is justified are elsewhere stated (p. 44 B). In describing the rocks of the region named, it will be most convenient to begin with the section afforded by Campbell Creek, in which strata of both these series appear to be represented.

Some account of a part of this section has been given in the report for 1877-78, but this included only the rocks seen near Shumway Lake, for which a thickness of about 500 feet was then ascertained.

Argillites and
amphibolites.

It is unnecessary to repeat this description, but it must now be noted, in respect to it, that a considerable part of the beds there spoken of as altered argillites have since proved, on microscopic examination by Mr. Ferrier, to be very fine-grained amphibolites, which undoubtedly represent volcanic rocks of some kind, either tufts or massive rocks dynamically altered. The alteration of the argillites proper is by no means great, and is chiefly confined to the immediate vicinity of the granitic intrusive masses.

Length of the
section

The section has now been extended by an examination along the entire portion of the valley of Campbell Creek occupied by the stratified rocks, with a length of nearly two miles from the north end of Shumway Lake north-eastward to the edge of the granite in that direction, and of about four miles southward to where the stratified rocks are again cut off by granitic rocks, near Newman's house, at the mouth of Fish Creek. The first part of this section crosses the strike of the beds at a considerable angle, while the second part does so very obliquely. The general direction of the strike is about N. 15° W., while the dips are to the westward at high angles, varying from about 70° to 40°. Both strike and dip are notably regular or this region, and rock exposures are frequent.

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SECT

Beginning with the section, the rocks representing order:—

- (4.) Fine-grained amphibolites, bedded and generally coming greenish-black.
- (3.) Massive, dark-green (possibly intrusive) argillites, with altered diabase (?)
- (1.) Chiefly green and gray with micaceous schists.

Total.

The rocks of Nos. 4 to 1 are referred to as the Campbell Creek section.

The argillites are often characterized by a fine-grained texture, that it is frequently difficult to distinguish between two classes of rocks. So bedding planes, from the mica, but it is common between the upper end of the section becomes considerable. This alteration is directly connected with the upper members of the section in character, and has produced an extreme term of this alteration where the strike of the beds is in conformity with the direction of the road going northward. The road going northward is found changing into all the different stages in the section.

On the hills to the east and on both sides of Fish Creek, as lenticular masses in the granite indicate these on the map, but they evidently represent volcanic rocks.

The upper part of the section, is that which is

*Appendix I., No. 8.
Proterobase or epidiorite.

Beginning with the lowest beds seen, at the north-eastern end of the section, the rocks represented may be described as follows, in ascending order:—

	Feet.
(4.) Fine-grained amphibolites and hard, splintery argillites, both well bedded and generally black or blackish, but occasionally becoming greenish-black.....	3,000
(3.) Massive, dark-greenish, rather coarse-grained diabase-porphry (possibly intrusive).....	600
(2.) Chiefly argillites, with fine-grained amphibolites and gray green altered diabase (?) all well bedded.*.....	2,200
(1.) Chiefly green and gray altered diabase (sometimes agglomerate) with micaceous schists, often well bedded.....	2,500
Total.....	8,300

The rocks of Nos. 4 to 2 inclusive of this section are subsequently referred to as the Campbell Creek beds.

The argillites are often calcareous, but they blend so completely with the fine-grained amphibolites of similar colour and macroscopic texture, that it is frequently difficult to draw any line between the two classes of rocks. Some of the rocks are slightly lustrous on the bedding planes, from the development of small quantities of microscopio mica, but it is only toward the southern end of the section, between the upper end of Shumway Lake and Newman's that the alteration becomes considerable and the beds assume a schistose appearance. This alteration is clearly of a local character, and is as evidently connected with the granite in this vicinity. It affects the upper members of the section, which are preponderantly diabase-like in character, and has produced micaceous and diabase schists. The extreme term of this alteration is found at the edge of the granite, where the strike of the bedded rocks turns more to the westward, in conformity with the direction of this edge. On the hill ascended by the road going northward from Newman's, dark greenish diabases may be found changing into much paler grayish, almost gneissic, rocks, and all the different stages in this change may be noted.†

On the hills to the east of Newman's, about a mile from the road, and on both sides of Fish Creek, similar rocks of gneissic aspect occur as lenticular masses in the granite. No attempt has been made to indicate these on the map, where they are included with the granite, but they evidently represent detached masses of the stratified volcanic rocks.

The upper part of this section, including about 2500 feet of beds, is that which is referred to the Nicola formation, while the

*Appendix I, No. 8.

Proterobase or epidiorite, according to Mr. Ferrier. Appendix I, No. 30.

Alteration of the rocks

Gneissic aspect of some.

Nature of the stratigraphical line.

lower members, or Campbell Creek beds, are assigned to the C che Creek formation. No unconformity was, however, observed here, and apart from general considerations derived from a study of other parts of the district, there would be no local necessity for any important line of separation. The dividing line is here based almost entirely on the fact that above a certain horizon diabases and diabase-like rocks prevail, while below it, the rocks are chiefly fine-grained amphibolites or argillites, the latter appearing to be lithologically connected with the C che Creek beds of the North Thompson, rather than with the great Triassic greenstone development of the Nicola formation. This line at least coincides with a marked change of conditions, and enables the separation on the map of a set of lower beds which in this region have peculiar characters and are pretty easily recognized wherever they occur.

Campbell
Creek beds
near Kam-
loops.

To the north-westward of the above-described section on Campbell Creek, and following the strike of its rocks, beds of identical character are found running on to the Thompson Valley. In the vicinity of Separation Lake and near the town of Kamloops, they consist chiefly of fine-grained blackish amphibolites and argillites, with grauwacke sandstones, containing in some cases fragments of hard black shales. These dip in various directions, and appear to be considerably disturbed and fractured, probably as a result of the proximity of the several granitic intrusions in this vicinity. They evidently represent, however, the lower part of the section seen on Campbell Creek, or that to which the name of Campbell Creek beds has been given.

Their junction
with Nicola
rocks.

The upper part of the Campbell Creek section is equally clearly represented by the greenish and gray diabases and diabase-conglomerates which lie below the Tertiary coal-bearing rocks near Guerin's, three miles south of Kamloops town, and form the ridge to the westward of the small stream which enters the Thompson at the old Hudson Bay house (at the west end of Kamloops), between the stream and the edge of the Tertiary.

As already stated, the line drawn between these two series of rocks is not entirely a satisfactory one, and it must, in fact, be regarded for the present as a provisional line only, for no unconformity nor any marked break has here been found. Had this particular tract in the vicinity of the town of Kamloops and Campbell Creek been alone examined, the two classes of rocks would undoubtedly have been considered as the upper and lower parts of a single series; but, being already in possession of the fact that the Carboniferous strata of the C che Creek formation characterize the region to the north-eastward,

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while those of the Nicola formation are characteristically developed to the south-westward, it becomes necessary to determine a line somewhere between them, and that above defined appears, in consideration of all the facts known, to be the most natural one.

To the north of the Thompson, the line of division is entered on the map in accordance with the same lithological basis, though, as already mentioned, it is very probable that the two formations are brought together in the region of the Garde Lafferty by faulting.

Stump Lake, Moore Creek and Upper Nicola.

To the south of the section on Campbell Creek, above described, after an interruption of some miles, occupied by the granitic and Tertiary rocks which surround Trapp Lake, the older rocks again reappear on the west side of Napier Lake and north of Fraser Creek. Where these rocks touch the shore of Napier Lake, they are not only close to the edge of the granite, but immediately underlie the massive volcanic rocks of the Tertiary, and have evidently been subjected to exceptional alteration by solfataric or similar action. They are much shattered, often highly silicified and pyritized and weather into rubbly red banks. Gray somewhat silvery schists, with some rather coarsely micaceous rocks of gneissic aspect, occur; but both these are associated with less altered porphyritic diabase in such a manner as to prove their origin from that rock. Within the area of the granite, a couple of miles eastward, gneissic intercalations also occur, like those described above near Newman's (p. 123 B). To the north of Fraser Creek, and again not far from the south edge of the granite, dark green diabase is found, coarsely porphyritic, and with uralite crystals.

Nicola rocks
near Napier
Lake.

Further to the south-west, about the actual head of Stump Lake, are much shattered and decomposed diabases, often highly dolomitized. The Tertiary volcanic rocks have evidently at one time extended over these, and the characters mentioned are often found in superficial parts of the older rocks in such a position. On the first small stream entering Stump Lake on the east, to the south of Fraser Creek, these rocks are followed by nearly black, very fine-grained amphibolites representing the Campbell Creek beds. These appear to be well stratified, and dip N. 60° E. < 80. From this place, similar rocks have been traced south-eastward, nearly on their line of strike, for about five miles, beyond which the country becomes so thickly wooded and broken that it was scarcely practicable to follow them. They are represented on the map as running out in this vicinity, though it is possible that they may be continued somewhat further. They are generally nearly or quite verti-

About north-
ern end of
Stump Lake.

cal, and the fine-grained black rocks are apparently in some beds true argillites, which occasionally show calcareous streaks and seem to be interbedded with green porphyritic diabases of the usual character, which to the south-eastward, became more altered.

Stratigraphical relations.

Thus far, from the vicinity of Napier Lake to the line of outcrop of the amphibolites and argillites, we evidently have represented the south-west side of a rather wide syncline repeating the rocks of the upper part of the section on Campbell Creek; but the thickness of the lower dark rocks here coming to the surface is very much less than that found in the Campbell Creek section, rendering it probable that they occur here either on the summit of a compressed anticline, or that they are cut off to the south-westward by a fault. The latter appears to be the more probable hypothesis, and a line of faulting running in a direction of about N. 20° W. would best accord with the observed facts. It may be added, that such a line if traced northward, is found to correspond with that of a fault noted as affecting at least the older portion of the Tertiary rocks on the south shore of Kamloops Lake, nearly opposite the mouth of the Tranquille River.

Development to the south.

To the south and east of the line of outcrop of the older rocks last referred to, the region including Stump Lake, Moore Creek, the Upper Nicola and the Douglas Plateau is occupied by rocks to which the map is afforded by the section on Campbell Creek. Much the greater part of this area is held by strata referred to the Nicola formation, including beds of that formation which must be stratigraphically much higher than those of any part of the Campbell Creek section. The remaining part of the area is occupied by the underlying dark amphibolites and argillites which have been provisionally attached to the Cache Creek formation. These are developed in greatest force about the Douglas Lake granitic mass, and there probably include beds lower than any seen on Campbell Creek. They also, however, probably occur in minor areas near the edges of the granite on Moore Creek.

Stratigraphy obscure.

This region is continuously bounded on the west by granite and extends to the east and south as far as the borders of the map, the only notable exception to its general character, being found in the occurrence of the Douglas Lake granite mass just alluded to. The western portion of this tract of country, particularly about Stump Lake, has been pretty closely examined, but with results which, in so far as any complete understanding of the geological structure is concerned, must be admitted to be unsatisfactory. The massive character of many of the rocks, with their often shattered state, render the dips

and strike distinct, the direction at right angles generally, are occasional.

That the element of porphyry these, a fine-grained simulation of similar.

The local element around Moore Creek, probably in places, in Stump Lake, appearing in Meander of diabase, ward from the map.

On the and near gray limestone is not the remains, (Creek) to be traced limestone the general bed is the south from nearly vertical, which, numerous originally or to child been into

and strikes very obscure in most places, and even when these are distinct, they are found to be irregular and conflicting. The general direction of strike is about north-west by south-east, but strikes nearly at right angles to this are not infrequent, while the beds, though generally dipping at high angles and sometimes vertical or nearly so, are occasionally almost flat.

That which is certain is that we have in this region a great development of altered diabbases, generally of green colours, and among which porphyritic (uralitic) varieties are particularly characteristic. With these, and forming a lower part of the series, is a great thickness of fine-grained well stratified blackish and dark gray amphibolites, often simulating altered argillites and passing in places into distinct argillites of similar dark colour.

General character of rocks.

The lower rocks last referred to are found in their greatest development around the Douglas Lake granite mass, but are also seen along Moore Creek near the bordering granite on that side. It appears probable that a synclinal axis runs southward between these two places, in a sinuous course, beginning near the north-west part of Stump Lake, passing near Rockford, crossing the Upper Nicola, and appearing again plainly in the well marked syncline examined in the Meander Hills (see p. 136 B). It is certain, at least, that a wide belt of diabase rocks of the general character above noted runs southward from the north end of Stump Lake to and beyond the border of the map.

Probable wide syncline.

On the west side of Stump Lake, a mile and a half from the shore and near the first small stream below the head of the lake, a bed of gray limestone was observed in association with the greenstones. It is not thick and is much broken, but contains some obscure organic remains, and resembles that met with on McDonald's River (Quilchenna Creek) to the south of Nicola Lake (p. 132 B). Although it cannot be traced out, and may even not be continuous, the occurrence of this limestone is interesting, as apparently fixing a horizon. Following the general run of the rocks, it is probable that the same limestone bed is that seen on the hills one mile east of the road and three miles south from Rockford. This strikes about north-and-south, and is nearly vertical. In thin sections this limestone has a greenish tint, which, under the microscope, is found to result from the inclusion of numerous small grains of a crystalline mineral. This has probably originally been pyroxene, but most of it is now changed to hornblende or to chlorite. The foreign constituent thus represented, has no doubt been introduced as a volcanic ash during the deposition of the lime-

Limestone beds.

stone, the circumstances being the same as those met with in the McDonald River limestone, described below.

It is believed that the two limestone outcrops referred to, represent points on the west side of the main syncline which has been suggested. No exposures of limestone on the opposite or east side were found, but, on the hypothesis advanced, the bed may be assumed to run along the hollow followed by the road to the east of Stump Lake, and to pass near to a point south-south-east of Rockford, three miles, where a diabase charged with small calcareous fragments was observed.

Rocks near
Dropping-
water Creek.

The following more detailed notes on the rocks of a few parts of this region may be useful :

To the west of Dropping-water Creek, and beyond the line of the Tertiary volcanic rocks in that direction, the older series is chiefly represented by dark green, gray-green and occasionally purplish, hard volcanic ash rocks or diabase-tuffs. With these are volcanic breccias of similar composition and some massive leek-green altered diabases of the usual kind. The fine-grained fragmental rocks are generally more or less calcareous, and are less indurated than most of the rocks in this region. Where the dip could be observed it is eastward at angles of 20° or 30° , and it is quite possible that these rocks may immediately overlie the horizon of the limestone above alluded to. They are identical in character with some of those found near Kamloops Lake and to the west of that lake in the vicinity of the Thompson River (pp. 119 B, 140 B).

Rocks of the character above described form a belt which runs nearly parallel to the edge of the Tertiary, and occupy much of the country between this edge and the upper part of Moore Creek. They are rather notably less altered than most of the rocks of similar composition found in the Stump Lake or Upper Nicola country; and it is also to be remarked that, though they immediately underlie the Tertiary volcanic rocks, they have not been shattered or dolomitized like those occupying a similar position at the head of Stump Lake (p. 125 B).

To the west of Stump Lake, between that lake and Moore Creek, the rocks observed, in addition to the limestone already mentioned, were green diabases, generally porphyritic with some exposures of a gray arkose grauwacke or quartzite.

Valley of Moore Creek. The valley of Moore Creek, running from north to south and ending at Nicola Lake, for fourteen miles nearly follows the junction of

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the Nicola rocks with the granite. The occurrence of this line of erosion is evidently dependent upon the contact of the two classes of rocks, though the actual stream lies persistently at a small distance to the eastward of the edge of the granite, which is somewhat flexuous. The granite border was traced out here in some detail, because of its possible bearings on the metalliferous deposits of the vicinity of Stump Lake.

In going southward along the valley for the first ten miles, the rocks in contact with or near the granite border all appear originally to have been diabases or felspathic rocks of volcanic origin, like most of those in this field. These have suffered considerable local alteration in the vicinity of the granite and are thrown there into rather irregular attitudes, in respect to their dip and strike. The special alteration referred to is usually very apparent at a distance of a mile from the granite, but extremely altered forms are found only much nearer to it. Close to the granites, the rocks are gray, rather than green in colour, often gneissic in appearance, and frequently become more or less schistose with the development of considerable quantities of black mica on the planes of foliation. Some of these rocks which have been microscopically examined have the composition of amphibolites in which traces are occasionally still visible of the usual porphyritic character of the diabases from which they have been derived,* but few of the amphibolites here met with have the fine grained and regularly bedded appearance of those characteristic of the lower part of the section on Campbell Creek, previously described.

Character of contact with granite mass.

Where the stratified rocks from a bay in the granite edge, about four miles north of Nicola Lake, the rocks above noted are, however, found to have in association with them some finely bedded hard argillite, of which the surfaces are very slightly micaceous. These are believed to be referable to the Campbell Creek beds of the C  che Creek formation.

Campbell Creek beds.

All these rocks are here traversed by numerous irregular and usually narrow quartz veins, but no granitic dykes were observed to cut them. The granite, near its junction with the stratified rocks is also somewhat modified, being in some places foliated parallel to the line of contact. In other places it becomes very fine grained and appears to consist entirely of feldspar and quartz. It is also usually charged with pyrites grains, weathering red in consequence, and is often more or less silicified throughout its mass, besides being traversed by numerous small veins of quartz.

Edge of the granite.

* Appendix I., Nos. 11 and 12.

Rocks near
Stump Lake
mines.

The principal known metalliferous deposits of the vicinity of Stump Lake, are comprised within an area of about five miles in length with a maximum width of three miles, situated on the south-east side of the lake. Here a large number of veins containing silver ores, with some gold, have been discovered, and a considerable amount of work of a preliminary kind has been done on them. The greater number of these veins run in bearings between N. 15° W. and N. 15° E. Some notes concerning them have been given in the Summary Reports for 1888 and 1890, and a more complete account appears on a later page of the present report.

The country-rock of the region traversed by these veins, is almost uniformly a dark green or green-gray diabase-porphry, in which large uraltite crystals are often conspicuous. There are, however, occasional bands consisting of diabase tuff, well bedded, with others of a fine gray felspathic rock, also well bedded, and possibly a few layers of fine amphibolite. A diabase tuff of the kind referred to was found at the "Planet" mine, near the shore of Stump Lake. The felsite-like rocks were observed in the valley traversed by the road to the east of the lake. Near the metalliferous veins, the rocks are often much shattered and weather red from the presence of iron pyrites or dolomite with which they are frequently charged.

Rocks sur-
rounding
Douglas Lake
granite.

Along the north-western side of the Douglas Lake granite, the country is deeply and nearly uniformly drift-covered, so much so that the boundary of the granite itself in this direction is somewhat uncertain, while very little is known of the rocks in its immediate vicinity, and the lines drawn upon the map must, in consequence, be considered as merely approximate. On the western and southern sides, however, the rocks are well shown in numerous places, and here the granite is found to be surrounded, for a width of about a mile and a half, with black and dark gray rocks of flaggy or schistose structure, consisting of argillites and fine grained amphibolites, with fine hard grauwacke sandstones, sometimes calcareous. These rocks evidently correspond with those of the lower part of the Campbell Creek section, but inasmuch as the distinction was not clearly made in the field between the fine amphibolites and the argillites, which they very closely resemble, it is not possible to state in what relative proportions the different classes of rock met with are present.

In one place, about half a mile east of the eastern extremity of the granite, rocks such as those above described were noticed to hold, apparently as interstratified masses, altered diabase-porphry of greenish colour, the circumstances being the same with those noted in part

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of the Campbell Creek section and also near the north end of Stump Lake, on its east side (pp. 123 B, 126 B).

The strikes of these rocks show a tendency to run in parallelism to the edge of the granite mass, and although there is some irregularity in this respect, as well as in that of the dip, the predominant dips are away from the granite at high angles. The impression conveyed is that the granite has been thrust upward, bearing the lower stratified beds, here seen, to the surface with it. No extreme alteration is observed along contacts with the granite in this case, though small quartz veins are rather abundant near it.

Relations to granite, and thickness.

The thickness of these beds near the Douglas Lake granite, is roughly estimated as 7000 or 8000 feet, and they are overlain by green and gray diabases of the usual kind. The relations which these two rocks are believed to hold in this part of the region, are shown on the general section which is next described, but their actual junction was not seen and it is not known whether it is a conformable or an unconformable one.

General Section near Nicola Lake and Eastward.

In 1877 it was found that the south side of Nicola Lake, from the vicinity of McDonald's River (Quilchenna Creek) westward to the lower end of the lake, a distance of seven miles and a half transverse to the general strike of the rocks, afforded a fairly good section of the series which was then named the Nicola series. The further examination of the country made in later years has led to the discovery of few better general sections of these rocks. In 1889 an endeavour was therefore made to supplement the results of the paced survey carried out in 1877 along the southern border of the lake, by means of a traverse running along the crest of the ridge which bounds this part of Nicola Lake on the south side. The results obtained, taken in connection with the previous observations, somewhat modify the outlines of the provisional section given in the first report, and afford the data for the section now presented, which though still perhaps not entirely free from doubt in regard to its details, is believed to afford a fairly correct idea of the composition and sequence of the rocks exposed. It has further been endeavoured to extend the original section eastward through the Meander Hills to the Douglas Lake granite area and to combine the results of the whole in a single diagram.

Examinations made of Nicola Lake section.

Though the greater part of this section (Section No. 4) lies a little beyond the southern border of the Kamloops sheet, no apology seems necessary in connecting its results with the report on that sheet, as it

Section No. 4.

throws light on the general structure of the Triassic rocks of the region reported on.

Strike of rocks
and trend of
section.

The main direction of strike of the rocks met with along the lake-shore and in the ridge behind it, is about N. 10° W., and this is preserved with considerable regularity, though on following the beds across to the north shore, where they are found in contact with the southern end of the great granite mass, they are found to turn more to the westward. It is in fact probably in connection with the intrusion of this granite that the beds included in the section have become flexed as they are.

The section now given, is supposed to be drawn along the crest of the ridge and not along the lake-shore as was the case with that of 1877, the discovery of four new limestone outcrops among the rocks met with on the ridge, having afforded a clue to the arrangement of the beds which was formerly wanting. As now presented, the section includes three synclinal and two anticlinal axes, and in describing it, the outcrops of the upper of the limestones believed to be comprised in the series—that first seen to the east on McDonald's River,—are assumed to be those defining the widths of the several synclinal and anticlinal folds.

Limestones at
McDonald's
River.

Beginning at McDonald's River (Quilchenna Creek), at a point about a mile back from the shore of the lake, the first wide low syncline is found to have a width of about two miles and three-quarters, its western edge being more steeply inclined than its eastern. The eastern outcrop of the limestone and the rocks near it are thus described in the report for 1877. Some of the details then given were for the purpose of establishing the fact that the limestone actually forms an intercalation in the great volcanic series here represented, a fact which can no longer be regarded as in any doubt.—

"The limestone bed above alluded to is seen on the west side of McDonald's River, about half a mile south of the wagon-road, where it forms a prominent bare cliff about sixty feet in height. It has been burnt here, and found to produce good lime. At first sight this bed appears to pass below the volcanic rocks with a low westward dip, but on more careful investigation it is found that it is separated from the mass of these rocks by a fault which runs about S. 14° E., with the downthrow probably on the west side. The existence of this fault is so far unfortunate as it to some extent obscures the relation of the limestone with the volcanic series, which is a matter of importance. I believe, however, that the very great probability—almost amounting to certainty—of the limestone belonging to the volcanic series can be shown in several ways.

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"The limestone is very much broken and disturbed, but on the whole appears to dip westward at an angle of about 20°. The volcanic rocks on the west side of the fault seem, in so far as their attitude can be ascertained, to lie in a similar position. In its normal form the limestone is gray, granular, but not very highly crystalline, evidently composed of organic fragments, among which joints of crinoidal stems are most abundant. A few obscure larger fossils are also occasionally present, including a *Terebratula*. In some places, however, it becomes filled with green granules, which project on weathering, and by examining various parts of the exposure these can be found at times to be much more abundant, so much so as to form a coherent mass after the whole of the calcite has been removed. In other layers the limestone is almost altogether replaced by this material, which is pale green in colour, and holds only scattered calcareous particles, among which crinoidal joints can at times be made out. On removing the limestone by an acid, the residuum appears to be felspathic, and fuses pretty readily on the edges before the blowpipe.* It resembles the finer constituents of some of the volcanic agglomerates to the westward, and has, without doubt, been a volcanic ash or sand, mingled in varying proportions with the limestone toward the close of its deposit. * * * On the opposite side of the fault the first rock seen is an amygdaloid, which, though its cavities are in places charged with a siliceous mineral, is generally highly calcareous, and in some layers appears to be more than half composed of calcite. Though, owing to the fault, the precise relation of this rock to the limestone can not be made out, it would appear that calcareous matter was still very abundant at the time the amygdaloidal material was poured out over the bottom."

Admixture with volcanic materials.

The amygdaloid last noticed may thus be supposed either to immediately overlie the limestone or to occur stratigraphically at a very short distance above it. The mass of this amygdaloid is a purplish and greenish altered diabase, and it has evidently in some places been originally an almost frothy scoriaceous volcanic rock. It is followed to the westward, in ascending order, by a great series of massive or brecciated diabase-porphyrites.† For several hundred feet above the limestone these are characterized by the frequent occurrence of purple colours, though green colours are also present. The higher beds become almost entirely green or greenish-gray, but do not otherwise materially differ from the lower. The thickness of these beds, above the limestone, appears to be about 2600 feet.

Overlying amygdaloid.

* On microscopical examination the green granules in the limestone are found to consist largely of hornblende, which is probably an alteration product of pyroxene, associated with some feldspar and a little quartz.

† Appendix I., Nos. 23, 33.

Limestone
west of first
syncline.

Where the limestone recurs on the west side of this syncline, it is again found to be overlain by a considerable thickness of notably purplish, porphyritic rocks, but these are here slightly schistose in character, doubtless as a consequence of the greater pressure to which they have been subjected. The limestone itself is again about sixty feet in thickness, and its connection with the volcanic rocks next underlying it is clearly shown. At its base it becomes interbedded with green feldspathic schists, which still afford evidence of their original fragmental character and undoubtedly represent altered ash rocks or tuffs.

Rocks of first
syncline.

In the centre of this first syncline and overlying the generally porphyritic diabases previously described, are certain bluish or greenish-gray fine-grained rocks, which belong to the highest part of the entire series represented in this section. Their thickness, as they are found in this syncline, appears to be small, but they recur in much greater volume in the westernmost syncline of the section, in which they continue as far as the lower end of Nicola Lake. No means was found of obtaining an approximately correct estimate of their thickness, but this must be at least several hundred feet. In some places they are very distinctly bedded and they evidently represent an altered condition of fine grained tuffs which have been deposited in water. They are believed to be equivalent to the highest beds met with in the Meander Hills, subsequently described.

Anticline
with two lime-
stone beds.

Returning to the last-described limestone outcrop.—This is followed to the westward by an anticline about a mile and three-quarters wide, bounded to the west by what is taken to be another exposure of the same limestone, with westerly dips at high angles. On this western side of the anticline, below the limestone mentioned, is another limestone outcrop which, unless some unrecognized complication occurs, must represent a second and underlying bed. This was, however, not seen on the eastern slope of the anticline. The strata intervening between the two limestones appear to have a thickness of about 1000 feet, which is characterized chiefly by coarse green diabase-breccia or agglomerate; and where this runs out upon the lake shore, it contains in some places large quantities of angular pieces of limestone, holding crinoidal fragments, and otherwise resembling the limestones of this series.

Schistose
rocks in anti-
cline.

Beneath the lower limestone, in the central part of this anticline, a thickness of about 2600 feet of beds not elsewhere seen in this part of the section, come to the surface. They consist for the most part of bright leek-green altered diabases, generally distinctly porphyritic and

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occasionally brecciated. Epidote has frequently been developed in the more compact varieties of this rock, but a large part of the entire thickness of these lower beds has been converted by pressure into green chloritic schists, between which and the compact forms transitional varieties occur. The schists are often highly calcareous, and it may be that the more calcareous beds have been those most affected by this alteration.

In the next small syncline to the westward, beds recur like those already described as overlying the upper limestone. These are here, as before, often purplish in colour and largely agglomeritic. Second syncline.

The next (and last) narrow anticline, to the westward, is believed to occur in the manner indicated, though the outcrop of the upper limestone which should appear on its west slope, was not seen. It seems that this anticline narrows and that its axis slopes down in a northerly direction, so that neither limestone comes to the surface on the lake shore, while the lower limestone can outcrop only to the south of the present line of section. In this anticline the rocks are again found to be rather schistose in character, in some places, particularly near the lake shore. Second anticline.

In the last low syncline, at the west end of the section, the exposures are very unsatisfactory, and its form as indicated is therefore largely conjectural. The characteristically purplish rocks previously noted were here not recognized, but green rocks of the usual character and often breccias are abundant on its eastern side, while the fine-grained felspathic materials forming the highest member of the section, appear to occupy a considerable breadth in its central part. Western low syncline.

With reference to that part of the section in the vicinity of Nicola Lake, above described, the following general points may be noticed. The diabases of the Nicola series are here, in many places, unusually charged with epidote, a fact which may probably be attributed to the proximity of the granite mass which comes out on the north shore of the lake. A greater development of schistose structure is found here than elsewhere commonly encountered in the Nicola rocks of this part of the Interior Plateau, and this is most prominent in the anticlines, especially toward their axes, where the beds stand at very high angles and appear to have had their original structure broken down by the intensity of the pressure exerted upon them. The two limestone beds are so inconsiderable in thickness that they may never have been absolutely continuous throughout the area covered by the section, while the recurrent explosive forces indicated by the massive volcanic breccias may easily have destroyed or removed the limestone. General character of rocks.

beds locally. This, in fact, becomes more than a mere probability, in cases where limestone fragments in quantity are components of the breccias.

Section east of
McDonald's
River.

An endeavour has been made to continue the section above described eastward and northward through the Meander Hills and as far as the Douglas Lake granite mass, thus to connect the rocks of the Nicola Lake section with the dark fine-grained argillites and amphibolites which surround that mass. The result of this attempt is shown in the eastern part of the general section presented, but in this part of the section it must be understood that the data are very much less precise than in the case of the section along Nicola Lake. The syncline found in the Meander Hills, in which occur well bedded fine-grained felspathic rocks almost certainly identical with the similar rocks found to form the upper members of the series near Nicola Lake, may be described as the ruling feature of this part of the section.

Syncline of
Meander
Hills.

These upper beds are here confined to the higher part of the hills, south of the Upper Nicola, and do not appear in the valley of the river. They consist chiefly of fine-grained felsites, of gray, greenish-gray and blackish tints when freshly broken, but which weather to various rusty colours. Some varieties break with a perfect conchoidal fracture. With these rocks, especially toward the base of this part of the series, are some fine-grained diabases, while the highest beds seen, resemble hard black argillites and probably contain a considerable proportion of ordinary argillaceous material. All these rocks are well and regularly bedded, in layers ranging from less than an inch to several feet in thickness. Like the rocks of the upper part of the Nicola Lake section above described, they resemble very closely the felsitic strata found in the vicinity of the Cretaceous area near Ashcroft, elsewhere noted (p. 113 B).

Highest beds.

Underlying
green dia-
bases.

To the west of the syncline thus occupied, between it and the line of McDonald's River and the shore of the upper part of Nicola Lake, hard gray-green and leek-green altered diabases of the usual kind prevail. These are generally more or less porphyritic and occasionally very markedly so. In one place, west of McDonald's River, considerable exposures were found of a hard green amygdaloid of which the base is coarsely porphyritic with urallite crystals. It is difficult to ascertain the attitude of these rocks, but where this was observed, they appear to lie at low angles, being in some cases nearly horizontal. The granite shown to underlie these rocks in the section, does not appear at the surface on the line of section, but occupies a considerable area near the shore of Nicola Lake half-way between the mouth of the Upper Nicola and McDonald's rivers. The limestone

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beds were not seen near the line of section anywhere to the east of McDonald's River, and may not be continuous in this part of the region.

To the east and north-east of the syncline, similar diabases are found in occasional exposures, till, on the north side of the Upper Nicola, below Douglas Lake, the underlying black argillites and amphibolites are reached.

In the subjoined recapitulation of the general section found in the vicinity of Nicola Lake and in that of the Upper Nicola River, the supposed order, with the approximately determined or estimated thickness of the various members of the section are given. These represent the Nicola formation, of which green diabases may be stated to be the characteristic rocks. The dark fine-grained amphibolites and argillites lie beneath the lowest beds included in this summary.

Recapitulation of section.

It will be noted that no limiting horizon has here been ascertained for the top of the section, which merely ends upward with the highest observed beds in the region. Also, that the lowest member of the section includes only the thickness brought to the surface in the main anticline on the south side of Nicola Lake. It is highly probable that a much greater thickness of the beds of this member is included in the eastern part of the section, where its actual base appears to be found in juxtaposition with the great series of argillites and amphibolites. The thickness of this member may in fact reach 6000 feet or more, but as already explained, the data found as to the attitude of the rocks in this part of the section are insufficient.

The order of the annexed summary section is descending:—

	Feet.
1. Hard, fine-grained generally well bedded rocks, chiefly felsites; thickness seen in Meander Hills (about).....	1,200
2. Altered diabase rocks, generally porphyritic, often brecciated; for the most part green but often purplish toward the base.....	2,600
3. Limestone (say)	50
4. Green altered diabase-porphyrines, mostly coarse breccias	1,000
5. Limestone (say).....	50
6. Green altered diabase-porphyrines, often brecciated, occasionally amygdaloidal; thickness seen near Nicola Lake (about).....	2,600
Total	7,500

Nicola formation to the south of Kamloops Lake and between the Moore Creek granite-mass and Guichon Creek.

The largest connected area believed to be occupied by rocks of the Nicola series, is that which runs southward from the middle part of Kamloops Lake to the edge of the map-sheet. This has a

Great area of Nicola rocks.

length of about forty miles, with an average width of perhaps twelve miles. It includes parts of the Timbered Hills, the valley of Meadow Creek, the Little Timbered Hills, and continues beyond the southern edge of the map to the Nicola River. The eastern and western sides of this area are formed in great part by granitic masses, but it is elsewhere bounded by overlapping Tertiary rocks. Though so extensive, but little detailed information respecting this tract of the Nicola rocks has been gained. It is for the most part densely wooded, and has therefore been examined along a few lines only, and then with difficulty. This being the case, it will be necessary merely to summarize the observations made.

Rocks near
Jacko Lake

From six to eight miles south of Kamloops, a projecting arm of the area of Nicola rocks above referred to, occurs in the vicinity of Jacko and Edith lakes. The country is here open and the exposures are fairly good. To the south of Peterson Creek, in the valley up which the trail going toward Trout Lake is shown to run, these rocks were examined with some care. They consist here for the most part of hard green diabase-tuffs, which in some cases show their bedding very clearly on weathered surface, but in others can scarcely be recognized as clastic till microscopically examined. Diabase agglomerates are also found, as well as some beds which appear to represent effusive materials of the same composition. These rocks dip north-eastward at angles of 45° to 60° . Their strike, if traced out to the south-eastward, appears to show that they represent the rocks met with to the north-west of Stump Lake (p. 128 B) which they resemble. They also closely resemble rocks seen to the east of the upper part of Moore Creek and to the south-east of Stump Lake (p. 130 B).

Relations to
other expo-
sures.

Contact with
granites.

On approaching the granitic area to the south-westward, these rocks become more or less markedly schistose. Near Peterson Creek, above Jacko Lake and about where the 3000-foot contour-line is shown to cross it on the map, gray and greenish, somewhat micaceous schists occur. On the west side of the creek, two or three miles further up, similar schists were found, together with some massive green diabase and rather extensive exposures of a peculiar green spotted schist, which in the large scale shows evidence of having been a diabase agglomerate. The actual junction with the granitic rocks was not seen, owing to the amount of drift covering, but the alteration seems to have extended further than usual from the intrusive mass. The foliation of the schists is not always parallel to the bedding, but is everywhere roughly parallel to the edge of the granite.

*Appendix I, No. 34.

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Along the stream which drains Edith Lake into Peterson Creek, Edith Lake. the diabase rocks are likewise much altered, being here near the margin of the granitoid or gabbro mass which runs from Cherry Bluff to Coal Hill and thence south-eastward. They were not, however, on this side observed to assume a schistose character, the appearance being rather that of a passage of the greenstones into the granitoid material.

Further to the west and north, on Alkali Creek, a couple of exposures of limestone were found, in which crinoidal remains were noted. They are much broken up and full of felspathic or siliceous material, but may be assigned with little doubt to the Nicola. Between these and the southern edge of the Tertiary volcanic rocks as marked on the map, crushed and highly silicified rocks, often pyritous, were seen in several places. It is impossible to tell the original character of these, but they also are assigned to the Nicola formation. Their alteration is probably connected with a line of fracture and disturbance which appears to run through from Copper Creek. Specimens of these pyritized rocks subjected to assay proved to contain no gold or silver.

Between Duffy Creek and Three-mile Creek, to the south of Kamloops Lake, an extensive area is occupied by rocks referred to the Nicola formation, but although considerable attention was devoted to these rocks, it has been found impossible to attain any certainty as to their arrangement or thickness. There is some evidence to show that an important fault cuts the lake shore about half-way between Six-mile Point and Three-mile Creek, running a few degrees east of south, and marked by a massive dyke of dark green-gray dolerite which forms a bluff on the lake a short distance west of the 229th mile-post on the railway. In this bluff a large fragment of conglomerate and limestone has been caught up, as described in my report of 1877.*

To the eastward of the line of the supposed fault, the general dip of the Nicola rocks appears to be easterly, but they are as a rule very massive. So far as made out, the lowest beds well exposed are those between Six-mile Point and the fault; and about a mile west of the point, in the hills south of the lake, a rather interesting development of exceptionally well bedded rocks occurs, D. N. 60° E. < 60°. These include at least thirty or forty feet of shaly beds, resembling argillites, of black and dull greenish colour, but evidently composed chiefly or wholly of tuffaceous material. They are interstratified with hard, greenish agglomerates, and with some soft fine-grained agglomeritic beds of a gray colour, in which some of the small frag-

* Report of Progress, Geol. Surv. Can., 1877-78, p. 118 b.

ments appear to be partly rounded by water action. These reappear about two miles to the south, on the wagon-road, where it skirts a small lake. The argillite-like beds resemble some found on the north side of Kamloops Lake to the west of Copper Creek.

Above and to the east of this well bedded zone, is a great mass of greenish, gray and sometimes purplish diabases, with little trace of bedding, but largely composed of agglomerates and hard tuffs. The latter are notably abundant in this region, they form a large part of the ridge of hills which runs south-eastward from Six-mile Point, crossing the wagon-road and then skirting it to the south all the way to Duffy Creek. A representative specimen of this material, collected near the 232nd mile-post on the railway, is described in the appendix.*

The rocks above described, seem to represent the upper rather than the lower part of the general section as shown south of Ashcroft, and may have a thickness of 5000 or 6000 feet.

Rocks west of
fault.

To the west of the line of fault, and between it and Three-mile Creek, the strata appear to have a general westerly dip at an average angle of perhaps 30°. This is best seen in general views of the hills from the north side of Kamloops Lake, the beds themselves presenting the usual difficulty on the ground. The mass of the rocks consists chiefly of diabase-agglomerates, here very often purple or purplish, but it includes one or possibly two beds of limestone, of which the thickness must be fifty feet or over in places. No fossils but obscure crinoidal remains could be found in the limestone outcrops. Two miles east along the wagon-road from Three-mile Creek, and near the supposed line of the fault, some small exposures occur of a limestone charged with well rounded small siliceous pebbles, apparently derived from the C  che Creek rocks. This dips westward at an angle of 20°, but its relations to the neighbouring rocks could not be made out. Between this outcrop and Three-mile Creek, it is possible that one or more small outliers of the Oligocene conglomerates remain, but some little exposures which were suspected to be of this character could not be clearly separated from the Nicola rocks.

Upper valley
of Three-mile
Creek.

Further up the valley of Three-mile Creek, on the east side, for about nine miles back from the lake, numerous exposures of rocks of the Nicola formation were examined. They are all much disturbed and very irregular, and offer no features requiring special mention, although the limestone appears to run on in this direction and some of the agglomerates (often purplish) are charged with numerous lime-

* Appendix I., No. 31.

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stone fragments. Similar diabases and diabase-agglomerates, but generally green, were found in the hills near the head of Duffy Creek.

It is very probable that a second important line of faulting follows the valley of Three-mile Creek.

Mention may be made here of a remarkable vein of siliceous dolomite which traverses these rocks near Duffy Creek. This appears to begin about one mile and a half south of the 233rd mile-post on the railway. It runs thence south-eastward along the slope of the hills for a couple of miles, to Duffy Creek, where it turns to a south-westward course, and was followed by Mr. McEvoy for about two miles further, along the north-west side of the creek. The vein is often a quarter of a mile in width, and, as specimens collected from it yielded a trace of gold on assay, it may be worthy of further examination. It precisely resembles in character the dolomite veins elsewhere found in this district, as, for instance, those of the southern part of the Garde Lafferty near Kamloops, but is much larger than any of these. It is probably referable to the same date with the other similar veins, and this, there is reason to believe, is later than that of the oldest Tertiary deposits (p. 163 B).

Dolomitic vein.

Traces of gold.

Near Savona, the rocks are chiefly green diabase-agglomerates, often notably coarse and porphyritic.

Savona.

About the head waters of Cherry Bluff Creek, greenstones of the usual character are found, but there is here also a small area of a diorite-like rock which is pretty evidently an intrusive mass, and is therefore indicated on the map under the same colour with the plutonic rocks generally.

Cherry Bluff Creek.

The tract forming the south-west slopes of the Timbered Hill with the plateau country southward to Meadow Creek, was examined along the exploratory line shown on the map and along the valley of Meadow Creek. The whole upper part of this valley, is wide and deeply filled with drift deposits, showing only here and there small isolated exposures of the underlying rock. The west edge of the granite, near Trout Lake, is entirely concealed, but near its assumed position green, schistose and slightly micaceous, much altered, diabase was found. This resembles some of the rocks seen in similar contiguity to granite on Peterson Creek (p. 138 B). Elsewhere along the valley, the rocks seem to consist of green and gray-green, with occasionally purplish, diabases, which are sometimes agglomeritic, but present no features of special interest. On the north side of the valley, three miles east of Guichon Creek and to the east of the

Valley of Meadow Creek.

projection of Tertiary volcanic rocks which occurs there, brownish and purplish grauwacke-like volcanic ash rocks are found, much like those of the vicinity of Three-mile Creek already described (p. 139 B).

Choo-whels
Mountain.

On the route from Trout Lake to Choo-whels Mountain, nearly all the rocks seen are greenstones of the usual character, which seldom show distinct bedding, though often consisting of coarse or fine diabase-agglomerate. In a few places the diabase was observed to assume a slightly schistose character. One of the agglomerates contains numerous fragments of limestone, most of which has been converted into greenish or reddish marble. Some of these are large and still show distinct traces of crinoid stems and other very obscure fossils, generally silicified. There are also some rounded pebbles present, which appear to show contemporaneous water action.

The southern point of Choo-whels Mountain, which was occupied as a transit station, is composed of a dark leek-green augite-porphyrity, somewhat less altered in appearance than most of the rocks of this region. From this point to Face Lake, diabases are seen in numerous exposures. These are usually greenish, but include also a notable proportion of purplish or reddish rocks of the same character.

Greenstone
Creek.

Similar rocks prevail along Greenstone Creek, but they are here nearly all green or gray-green in colour. About a mile and a half below Big-fish Lake, on this creek, where its valley makes a right-angled turn to the south, there are, however, some exposures of rocks differing in character. These are gray or blackish in colour, well bedded in thin layers, and are found on microscopic examination to be composed of siliceous and tuffaceous matter intermixed.* Macroscopically they much resemble some rocks noted near Peterson Creek (p. 138 B). In certain layers they contain numerous small calcareous fragments, and with these rocks there appears to be associated some slaty or schistose argillite, though this was not actually seen in place. The dips are eastward, at rather high angles. It appears not improbable that the horizon here represented may be the same with that of the argillites noted in the hills to the north of Savona (p. 121 B) though no fossils were found at this place.

Rock south of
Meadow
Creek.

Several excursions were made from Meadow Creek into the country to the south, but this is not only for the most part thickly wooded, but also heavily drift-covered. These difficulties are especially great toward the edge of the granite on the east, and about the head of the west branch of Moore Creek, so that the line between the Nicola rocks and the granites in this region is far from being very definitely fixed.

*Appendix I., No. 36.

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In the rocks met with to the south of Meadow Creek, the only notable feature is the unusual abundance of amygdaloidal diabase-porphyrates, which are sometimes green, but more commonly purple in colour. These are comparatively little altered. The amygdaloidal cavities are often nearly spherical and are filled chiefly with zeolites together with some calcite.* Rocks of this class appear near Meadow Creek about four miles above its mouth, and run thence in a south-easterly direction, gradually departing from the line of the stream, for about six miles. They closely resemble the purplish amygdaloids found not far above the limestone on McDonald's River (p. 133 n) and though the attitude of the beds could not be determined, it is possible that they dip eastward or north-eastward and pass beneath the rocks last described on Greenstone Creek, in which case the section here might be found to repeat the conditions of that observed between the Deadman River and the summit of the hills north of Savona (p. 121 n).

Among masses of rock brought down by a stream which enters Guichon Creek from the east between Meadow Creek and the head of Mamit Lake, gray fine-grained limestone with obscure traces of fossils was found. This was seen to be associated in the same fragment with greenstone rocks, and it is probable that an outcrop of one of the limestones of the Nicola formation occurs to the east of Guichon Valley not far from this place. It may further be observed here, that some evidence of the probable occurrence of a small outlier or outliers, or of intrusive masses of Tertiary volcanic rocks was met with in this vicinity, though no such rocks were actually seen in place.

Further south, on Ray Creek, the rocks seen all belong to the greenstone series. They are hard and often contain some epidote, and are generally much shattered by jointage planes. Similar rocks appear to characterize the whole region in this vicinity. At the extreme head of Clapperton Creek and on the adjacent crest of the Little Timbered Hills, where the Nicola rocks form a bay in the edge of the granite, they are found in various stages of alteration, sometimes resembling diorites, and elsewhere, near the actual border of the granite, becoming gneissic in appearance or forming thinly foliated and highly micaceous schists. The strike is here, locally, nearly east-and-west. Small quartz veins are frequent in these altered rocks, and they are also cut by granitic veins or dykes. On the lower part of Clapperton Creek, the rocks are seldom well seen, but they appear to consist wholly of diabases or associated materials, generally greenish. To the west of Clapperton Creek, along the border of the projection of Tertiary rocks shown on

*Appendix I., Nos. 24 and 27.

the map, the Nicola series is represented by bright greenish amygdaloids and agglomerates, the latter passing into tuffs, and then becoming somewhat calcareous. On the west side of the same projection, the underlying rocks, where seen, consist of brown and purple-brown augite-porphyrite, with abundant felspar crystals and a little quartz. These are elsewhere referred to in connection with their relation to the Tertiary rocks (p. 195 B).

Junction with
granites on
Guichon
Creek.

The wide and deep hollow now occupied by Guichon Creek, like the corresponding depression of Moore Creek, has been excavated along the line of junction of the Nicola rocks with the granite. Its existence has undoubtedly been determined by that of this junction, and although the stratified rocks are usually hardened on their approach to the granites, it may be supposed that the facility of excavation evidenced has been due to the much shattered state in which these rocks are often found when thus situated. In general, this valley is now deeply filled with drift deposits, but sufficient exposures of the older rocks have been found to enable the line of junction to be traced with approximate accuracy. Opposite the mouth of Meadow Creek, along the base of the hills which border Guichon Creek valley, the actual contact of the Nicola rocks with the granite is pretty well seen. The diabases become schistose and almost gneissic in appearance, while the margin of the granite itself has been crushed into a foliated material of gneissic aspect and gray colour. It was also observed here that the granite, at some distance from its actual edge, is charged with angular fragments of the greenstones, still plainly distinguishable from it.*

A great area
of green-
stone.

Speaking generally of the large area of rocks of the Nicola formation to which the foregoing brief notes apply, it may be described as being characterized throughout, so far as our present knowledge goes, by altered volcanic products. It is in fact a great region of "greenstone," which is usually found to have the composition of an altered diabase, and often appears in the form of agglomerates, sometimes as amygdaloids, and occasionally as fine ash rocks or tuffs.

Limestone
and argillites.

The occurrence of limestone, as near Three-mile Creek, and of argillite-like materials, as on Greenstone Creek, with the evidence of underlying limestone afforded by the calcareous agglomerate of the south-east slope of Choo-whels Mountain, are quite exceptional. These at the same time must be regarded as most important exceptions, for they appear to offer a means of eventually determining and tracing out horizons, and of bringing these into comparison with those recognized on Nicola Lake and elsewhere. The attitude of the beds is so

* Cf. Annual Report Geol. Surv. Can., vol. II. (N.S.), p. 11 B.

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seldom observable, that the order and thickness of the series here remains indeterminate. The structure appears, however, to be in the main a synclinal one, resting between the eastern and western granitic masses. The general direction of strike seems to be about N. 40° W., and the highest beds found are probably those of the vicinity of Big-fish Lake. The general synclinal structure, if such it be, is, however, evidently complicated by several superposed minor folds, but no evidence has been discovered of acute crumpling or of great disturbance, except in certain places toward the edges of the area.

General
structure.

*Rocks of the Nicola formation, seen on and near the Upper
Deadman River.*

Passing over the region in the vicinity of the Thompson River above Ashcroft, and that of the western part of Kamloops Lake, a description of which has already been given in connection with one of the general sections, (p. 115 B) it remains to add a few words respecting the older rocks shown along the northern part of the Deadman River and its branches where these streams have cut through the Tertiary volcanic strata. The rocks thus shown are believed to be referable to the Nicola formation.

The valley of Criss Creek, for about ten miles above its junction with that of the Deadman, appears to be continuously cut down to and into, the older rocks. These, so far as observed, and with the exception of one thin bed of limestone near the lower part of the creek, consist entirely of greenstones and porphyrites, and are probably for the most part diabases in composition. In colour, they are green, gray and blue-gray.

Criss Creek.

Two miles above the mouth of Criss Creek, the main valley of the Deadman is found to be floored by greenstones, which continue along it for about a mile and a half. These, according to Mr. McEvoy, are dark green diabases. After a short interruption caused by Tertiary rocks extending across the valley, the older rocks are again found, and they continue in the bottom of the valley for above eight miles, or nearly to the lower end of Deadman Lake. Just about the mouth of Gorge Creek, extending thence up stream for a distance of about a mile, is a hard breccia or sub-angular conglomerate, composed chiefly of greenstone fragments with some of granite and of fine grained limestone. This has a calcareous cement, and is somewhat different in character from the conglomerates usually met with, resembling the rock seen east of Three-mile Creek (p. 140 B). It is followed to the north by an ordinary dark green diabase-agglomerate; and rocks of

Deadman
River above
Criss Creek.

the same character, though often apparently massive rather than agglomeritic, continue to floor the valley to the point above designated, where the Tertiary rocks again extend completely across it.

To the north of Deadman Lake, the old rocks reappear in the bottom of the valley and seem to be continuously shown, according to Mr. McEvoy, for more than seven miles. They consist of greenstones, differing from those seen further down the valley only in being somewhat more highly indurated and altered. They become coarsely crystalline on approaching the edge of the great granite region on the north.

Bonaparte
River.

In this vicinity, a few miles to the north westward, on the Bonaparte below the mouth of its north branch, a small area of fine-grained green diabase was observed to occur in the river-valley, between the margin of the granite and the overlapping edge of the Tertiary rocks on the west.

Uren's.

Following the main stream of the Deadman to the eastward, above Hunters Creek, it would appear that the volcanic rocks of the Tertiary have been removed for a considerable area near Uren's, as marked on the map. This area seems to be occupied in part by bedded greenstones, in part by diorite, but it is so heavily drift-covered that its extent as well as the relative proportions and outlines of the two classes of rocks are doubtful.

Granite Lake.

Still further up, the valley, for a distance of nearly three miles below Granite Lake, is again floored by old stratified greenstones, which, so far as their attitude could be observed, appeared to strike about east-and-west and to be nearly vertical. These rocks are sometimes more nearly blackish than greenish in colour, and appear now to be fine-grained diorites rather than diabases. They are occasionally schistose, and probably owe their present appearance to their proximity to the great granitic mass of the Bonaparte Lake region. Granite Lake is itself surrounded by granitic rocks, but in these, on its south shore, are numerous large fragments of greenish dioritic rock, with some of hornblende-schist, the appearance being that frequently characteristic of the vicinity of the border of the granitic masses where they meet the stratified greenstones. It is entirely doubtful whether the greenstones found in this particular area should be classed with the Nicola formation, as no definite evidence as to their age could be obtained.

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CRETACEOUS ROCKS.

Fraser River Area.

The principal area of Cretaceous rocks included in the Kamloops sheet, takes the form of a narrow band, which, entering the southern edge of the map, pursues a remarkably direct course of about N. 20° W. till it passes obliquely across its western edge. The whole length of this band, within the map, is about fifty-six miles, its greatest width about seven miles. It may be regarded as defining the inner or eastern margin of the wide mountainous zone formed by the Coast Ranges. In a general way, it must be understood to occupy a syncline on the eastern side of these ranges; but its occurrence there is also, no doubt, largely due to faulting, parallel to its general direction. The actual position of the Fraser River, within the limits of the map, has evidently been determined chiefly by the existence of this Cretaceous band, or by the folding and faulting which have here defined it. For a distance of over forty miles, from the mouth of Bridge River to the southern edge of the map, the Fraser almost exactly follows the main strike of the Cretaceous rocks. Above Bridge River it breaks across the Cretaceous belt and thereafter, to the western edge of the map, its valley lies to the eastward of this belt.

General relations of Fraser River area.

From the southern edge of the map, as far north as the mouth of the Thompson, the Cretaceous rocks are chiefly represented on the west side of the Fraser. The main direction of strike is generally nearly parallel to that of the valley, but to this there are numerous exceptions. The beds are much disturbed and broken, and probably consist of several crushed folds, as dips occur both in eastward and westward directions.

Region south of Lytton.

The rocks are chiefly greenish and gray-green, hard grauwacke or tuffaceous sandstones, with some conglomerate and a little shaly argillite. Where crossed on the route to Kl-ow-a Mountain, the Cretaceous rocks have a width of a mile and a half to the west of the Fraser, but between this point and Stein Creek their width has not been accurately determined.

On Stein Creek, the Cretaceous rocks have a width of nearly two miles to the west of the Fraser, occupying not only the flat land near the river, but forming also the lower tier of hills along the base of the main range. Sandstones and shaly beds of the usual character prevail; but in this vicinity, on both sides of the river, entire masses of the rocks have become reddened and decomposed by action subsequent

On Stein Creek.

to their deposition. The beds are all much shattered, and lines of faulting in this place undoubtedly run along the valley, one of which apparently bounds the Cretaceous trough on the east side of the valley. The conglomerates here hold rather more granitic material than usual.

Freshwater
fossils.

Below the bridge on Stein Creek, where the rocks are several times folded, a bed of gray, crumbling, sandy shale was found to contain numerous fossils. These are, unfortunately, badly preserved, but are apparently fresh water forms, one of which may be a *Goniobasis*. Some fragments of large fin-spines of a Selachian fish were also found, measuring more than half an inch in greatest diameter, and either nearly triangular or laterally compressed in cross-section.

Fossil plants.

On the east side of the Fraser, about a mile above the mouth of Stein Creek, numerous exposures of Cretaceous rocks occur in a number of transverse gullies which are crossed by the trail. Blackish, shaly, and evidently carbonaceous beds, are here somewhat more abundant than usual, and from these a few fragmentary plant remains were collected in 1877, and a somewhat better, though still very small, collection, was made in 1890. Sir J. Wm. Dawson has described the first collection as containing two indeterminable dicotyledonous leaves and one flabellate leaf resembling that of a *Salisburya*.* On the second collection, he supplies the following note:—

"1. *Platanus obtusiloba*, Lesq., or closely allied. This is a species found in the Dakota group in Nebraska.

"2. Probably *Magnolia tenuifolia*, Lesq., which is found in the Dakota of Nebraska and also in the Dunvegan group of Peace River.

"3. *Menispermities*, allied to *M. grandis* of the Dakota group, but probably specifically different.

"4. *Laurophyllum*. Several leaves referable to this genus, and near the Dakota species.

"5. *Sequoia*, a fragment which may be *S. Reichenbachii*.

"6. Grass-like stem or *Phragmites*, *Carpolites*, etc.—scarcely determinable.

"The whole probably belongs approximately to the age of the Dakota group or near to this."

Stein Creek to
La-loo-wissin
Creek.

Further up the Fraser Valley, the principal development of Cretaceous rocks continues to lie to the west of the river as far as La-loo-wissin Creek, and these often rise into hills of 2000 to 3000 feet in height on the flanks of the mountains there. The rocks met with are

* Report of Progress, Geol. Surv. Can., 1877-78, p. 110 B.

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all so much like those already described, that it is unnecessary to enter into any detail respecting them. Evidence of great disturbance and crushing are everywhere found in the shattered condition of the beds, the recurrence of reddened zones, and occasionally of friction, or crush-breccias.

Beyond La-loo-wissin Creek, the greater part of the Cretaceous belt lies to the east of the Fraser River, though detached selvages continue to appear on the west bank also. In one of the latter, three miles above In-ti-pam Creek, numerous specimens of *Aucella Mosquensis* var. *concentrica* were found, in a hard black flaggy argillite. These are all considerably distorted by pressure. At this place and in the next considerable strip of Cretaceous on the west side of the river, near Texas Creek, hard, black argillites and fine grained blackish sandstones are more than usually abundant, and it is probable that the lower part of the formation, corresponding with that seen near Lillooet and Bridge River, is here chiefly represented.

Thence to
Texas Creek.

At the mouth of Texas Creek, below the bridge, cliffs are found composed of completely shattered black Cretaceous argillites, in which the fragments have since been re-cemented by the introduction of ferruginous material. These rocks have evidently been shattered in place, and they may be regarded as representing a species of friction-breccia. The shattered zone, which is of considerable width, crosses the Fraser River to the southern end of the Great Rock-slide, this remarkable feature being in fact due to the comminuted character of the rocks which have supplied its materials.

Breccias at
Texas Creek.

Fountain Ridge, appears to be entirely composed of Cretaceous rocks, bounded by the newer volcanic rocks of the Tertiary on the east, along the line of the Three-lake Valley and by Palaeozoic rocks on the west; the line here nearly coinciding with the Fraser, till in the vicinity of Lillooet it crosses the river obliquely and includes the north-eastern slopes of McLean Mountain. The general structure of Fountain Ridge is that of a syncline, which appears to be simple in its southern part, but becomes wider and more irregular and complicated to the north. More or less faulting is suspected to exist along both the eastern and western borders of the Cretaceous, evidence of which seems to be given by irregularities of strike, and the broken and often silicified character of the rocks in many places near these lines, as for instance in the neighbourhood of the bridge at Lillooet.

Fountain
Ridge.

Some miles above Lillooet, the Fraser River breaks completely across the belt of Cretaceous rocks, from east to west, a circumstance

Rocks above
Lillooet.

probably due to the existence of an imperfect transverse anticlinal flexure, by which the rocks here appear to have been affected; but though both sides of this part of the river have now been examined, the irregularities found are such that no really satisfactory general section has been obtained.

About half a mile north of Lillooet, rocks evidently belonging to the Cretaceous series, consisting of hard, blackish argillites, are found. Further north, near the Lillooet Bridge, similar rocks occur, in association with blackish quartzites, and materials of the same kind continue along the west side of the Fraser to the mouth of Bridge River. These are usually blackish, gray or greenish well-bedded quartzites, often much shattered and pyritized, and thus producing by weathering, bands of a rusty colour. These rocks, between Lillooet and Bridge River, have, as a rule, easterly dips, at an average angle of 60° , but varying from about 50° to vertical. They are all very much disturbed and irregular and have been highly silicified.

Bridge River. At the mouth of Bridge River, where a considerable area has been stripped of its superficial deposits by placer miners many years ago, extensive exposures are found of black, gray and banded quartzites, with hard, black, shaly beds, and some thick layers of gray-green sandstone which pass into fine conglomerates. Bands of pyritized rusty rocks run both with and across the strike, which is here pretty uniformly S. 25° E., the beds standing vertically. The valley of Bridge River has been cut out along the strike of these rocks, as far as the edge of the present map and further. The beds found along it are either vertical or have high north-easterly dips; but in the hills to the north-east of the river, the angles are lower, and hard, greenish-gray sandstones and conglomerates prevail. At the summit of the mountain ridge which runs parallel to Bridge River on that side, these dips become reversed, and the same beds occur in nearly vertical attitudes.

Transverse section above Bridge River. A short distance above the mouth of Bridge River, what is pretty evidently a compressed anticline crosses the Fraser, and in this, blackish beds are again seen. This is followed to the eastward by a second syncline, of which Fountain Peak, forming the northern and culminating point of Fountain Ridge, occupies the central part. All the higher parts of this peak and its dependent range appear to be composed of the greenish-gray hard sandstones and conglomerates. To the east of the peak, near the lower part of Fountain Creek, varying and confused dips are again found. In the gorge at the mouth of the creek, the beds dip away from the stream on both sides,

Mouth of Fountain Creek.

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and it at first seemed probable that here an unconformable overlap of Tertiary sandstones occurred, upon upturned Cretaceous beds; for the strata on the east side are comparatively soft and crumbling, while those on the west side have the usual hardened character of the Cretaceous rocks. It appears certain, however, that on the east side of the gorge a compressed and partly overturned anticline occurs, that the rocks on both sides are Cretaceous, and that the less indurated character of those on the east side is due to subsequent decomposition effected by acid vapours or by some form of solfataric action consequent on the volcanic eruptions of the Tertiary period.

To the east of Fountain Creek, Cretaceous rocks, generally sandstones, are found in various stages of alteration, but with low southerly dips. They are here not only much shattered and reddened, but also as a rule highly silicified; and it was in consequence of the changes thus produced in their appearance, that no precise line was discovered between them and the distinctly volcanic rocks next met with, in 1877, when it was supposed that the latter constituted an underlying part of the same Cretaceous formation. A more detailed examination of the region, in the light of further study of the formations elsewhere, has since afforded grounds for reversing this opinion.

Silicified Cretaceous rocks.

Thus, speaking generally of the Cretaceous rocks of this area, it may be said that they consist of highly indurated sandstones, argillites and conglomerates. The sandstones are most commonly of greenish-gray colours, passing on one hand into coarse, distinctively green rocks, largely composed of arkose materials derived from the older greenstones and granites, on the other, with fine-grained blackish sandstones which grade down imperceptibly into argillites of the same colour. Few of the sandstones are distinctly siliceous except where subsequently silicified, and many of them hold pebbles here and there. The argillites are generally black or nearly so, but often notably banded by lighter colours along the bedding planes and not seldom carbonaceous. The conglomerates are composed of well rounded pebbles, among which those of cherty quartzites and granitoid rocks are probably, as a rule, the most abundant, though greenstones, black argillites and porphyrites are also represented, and limestone, though occasionally found, is notably scarce. Many of the rounded masses are as much as a foot in diameter. The paste of the conglomerates is, usually, a coarse-grained greenish grauwacke.*

General character of rocks.

*A collection of pebbles, made from the Cretaceous conglomerates of Fountain Ridge, near the northernmost lake in the Three-lake Valley, has been macroscopically examined by Mr. Ferrier. The materials represented are, in order of importance, as follows:—Fine-grained eruptives of various kinds, diabases, diorites, granites, with one specimen of apparently an impure limestone.

Order of superposition.

Respecting the order of superposition of these beds, it may be stated that the blackish sandstones, quartzites and argillite form the mass of the lower part of the formation, while the greenish and gray sandstones and quartzites, with the conglomerates, characterize its upper parts, and constitute the higher crests of Fountain Ridge and other mountainous elevations. None of these rocks are, however, confined to the upper or lower parts of the formation, for blackish argillites occur at various horizons throughout and the same is true of the conglomerates.

A line of weakness.

The whole of this great mass of rocks, is here found crushed together in a series of rather strict folds on the eastern edge of the great elevation of the Coast Ranges, the area which they now characterize having, for some reason, proved to be the line of least resistance and minimum strength during one at least of the periods of Cordillerian folding.

Thickness of the series.

In respect to the thickness of the Cretaceous rocks, the best evidence to be found in the area of the Kamloops sheet, though admittedly very imperfect, is that obtained in this particular district. To the south of Lillooet, on the east side of the Fraser, the Cretaceous rocks form for some miles a great range of vertical cliffs, in which the beds have rather low easterly dips. These cliffs show sheer rock-faces of about 2000 feet, and these, taken in conjunction with the outcrops nearer the river, must represent a thickness of at least 3000 feet of strata. But an examination of the sections as a whole, shows that the rocks thus exposed can constitute but a portion of the entire volume, and indicates that this must exceed 7000 feet, while it is very probably 10,000 feet or more.

Pyritous zones.

The occurrence of pyritized shattered and now rusty zones in these rocks has already been remarked. This is not uncommon, and has attracted attention in consequence of the possible occurrence of gold in such zones, although assays made of a few of these materials have not shown the presence of any gold. Another interesting point, is the occurrence of granitic intrusions, of the nature of large dykes, in these Cretaceous rocks, a fact which shows that some at least of the granites of the region must be of post-Cretaceous ages (p. 241 B).^{*} It may also be noted, that the green colour and arkose character of many of the sandstones, renders it occasionally difficult to distinguish them in broken or poor exposures, from the greenish tuffaceous rocks of the Tertiary on the one hand and from the tuffaceous greenstones of the older series (from which their material has been derived) on the other. This is especially the case along the Three-lake Valley, but the

Post-Cretaceous granites.

Outlines on map.

^{*} See Appendix I., Nos. 38, 39 and 40.

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line of division as now established there, is believed to be practically correct.

The only fossils obtained in this part of the region are a few specimens of *Pecten* (*Synsyclonema*) *Meekiana*, found a short distance to the west of Fountain house. Fossils.

To the north of the vicinity of Fountain, the Fraser lies nearly along the east edge of the Cretaceous for about five miles, after which this edge gradually leaves the vicinity of the river and runs up the wide valley of Red Creek. Rocks north of Fountain.

Hard greenish sandstones of the usual character are the most abundant rocks along this part of the Fraser Valley, though some carbonaceous shaly layers also occur, as well as beds of conglomerate. The dips are generally westward. At a short distance below Black Hill Creek, and thence onward along the river and trail, the sandstones are somewhat different in character. They are completely shattered and rubby, apparently considerably decomposed, and almost entirely formed of paler, greenish-gray, arkose material derived from granitic rocks. The apparent decomposition of these rocks may of course be due to the fact that they have never been penetrated by the silicifying matter to which the general induration of the sandstones is attributable, but it is equally probable that they have been affected by emanations due to the Tertiary volcanic period, in the manner suggested in the case of the similar rocks at the mouth of Fountain Creek (p. 151 B). The shattered condition of the rocks is almost certainly due to their proximity to the zone of volcanic action, and is very probably accompanied by faulting. It is thus uncertain whether these softer and paler arkose rocks represent a special horizon, but they very closely resemble some of the Cretaceous rocks met with on the Skagit River in 1877.* Cliffs of these rocks, of striking appearance and boldness, occur about the mouth of Black Hill Creek. At Black Hill Creek.

Along the west side of Red Creek valley, the Cretaceous rocks form a rather bold escarpment, dipping westward, generally at high angles. They appear to consist almost entirely of gray-green sandstones, and in large part of arkose and not highly indurated beds, like those above described. The Cretaceous rocks of the Camelsfoot Mountains, to the westward of the Fraser and Red Creek, were well seen from distant high points, but have not been examined in detail. The dips appear generally to be comparatively low in the central parts of this range. Red Creek.

Botanie Creek Area.

The small detached area of Cretaceous rocks shown to occur near the mouth of Botanie Creek, about two miles from Lytton, consists of Botanie Creek area.

* Report of Progress, Geol. Surv. Can., 1877-78, p. 106 B.

blackish and brownish shales, hard gray sandstones, and conglomerates, all much disturbed. The conglomerates particularly, are also completely reddened, while the other rocks are generally shattered and slickensided. These beds, on the east side, are evidently faulted down against the granitic rocks, while a second fault probably runs along the west base of the small, scarped granitic ridge which is a prominent feature from the river. The actual area of the Cretaceous beds here is indeterminate, for they may extend further up the Botanie Valley than is now known, beneath the flat terraced land which occurs in it. A few small fragmentary fish-bones were here found in some of the shales, with what are apparently the crushed tests of minute *Ostracoda*.

Ashcroft Area.

Ashcroft area. This Cretaceous area may be referred to as the Ashcroft area, the town and station of Ashcroft being situated nearly in its centre, in a comparatively wide and low tract of land which is dependent on the existence of the Cretaceous rocks. It is about four miles in average width, with a length of about eleven miles, and for the greater portion of this length the Thompson River follows its axial line.

General arrangement. The rocks consist of sandstones, conglomerates, and dark shales, the shales here apparently preponderating in the upper part of the series, and occupying in the main the central part of the area, while the sandstones and conglomerates are more abundant and characteristic in the lower parts. There is, however, throughout, a considerable amount of alternation of all three classes of rocks, and no easily defined line of separation has been observed in the entire series.

Sandstones. The general lithological character of the strata in this area is closely akin to that of those of the more important Cretaceous region of the Fraser Valley. The sandstones are usually greenish or greenish-gray in colour, being largely composed of debris of the underlying diabases and felspathic rocks, and seldom or never purely siliceous. They vary in texture from very coarse grits and grauwackes, to materials of which the constituents are indistinguishable to the unaided eye. In many cases they are extremely hard. The shales are blackish, and their sombre outcrop along the Thompson has given its name to Black Cañon. With the shaly part of the series, some nearly black sandstones occur, but it is also in association with the shales that the distinctively gray sandstones are usually found.

Conglomerates. The conglomerates were nowhere in this area observed in great thickness. Their material is very varied in origin, but like the grits,

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into which their finer varieties pass, largely composed of diabase or felsite. Pebbles of cherty quartzite, granite and gray limestone, are also abundant in some places. The component fragments are often well rounded, but in some beds are angular and unworn. This is especially the case near the base of the series, which appears to have been rapidly built up of materials produced by sub-aërial waste of the older rocks of the vicinity.

Breccia-like rocks of this character, but slightly water-rounded, and somewhat calcareous, are well shown in the ridge to the east of the wagon-road on the west side of the river, about a mile south of Cornwall Creek. They rest directly upon a rather fine-grained purplish calcareous agglomerate, which is more compact than the Cretaceous rocks above it, and is almost identical in character with that described as occurring in the Nicola formation, near Penny station (p. 119 B). The lower agglomerate is here also believed to be referable to the Nicola formation. Similar breccia-like rocks are abundant near the margin of the Cretaceous in the valley of the Bonaparte, about three miles above the mouth of that river. Breccias.

No fossils have been found in any part of this area, but its lithological identity with the Cretaceous of adjacent parts of the Fraser Valley, is sufficient to fix its Cretaceous age.

The rocks are nearly everywhere much disturbed and crushed, and no satisfactory general section has been obtained of them. Nearly all the observed dips are to the westward, but as a rule those on the eastern side of the middle line of the area are comparatively low, ranging from 10° to 45° , while those of the western side are often at angles of 60° and from that to vertical. It is thus probable that the structure of the area as a whole is that of a syncline, of which the western limb has been more or less completely overturned by pressure acting from the west. There are, however, undoubtedly, minor folds, and numerous indications of faulting are also found. The thickness of the entire series may be stated as at least 5000 feet, although it is very possibly much more. (See Section No. 1). Structure.

On the western edge of this Cretaceous area, the following notes may be added:—From the vicinity of Jack's Creek northward, for a couple of miles, the margin of the Cretaceous appears to be formed by a coarse conglomerate, generally with very high westward dips. At the place already referred to, about a mile south of Cornwall Creek and on the wagon-road, the rocks are found dipping eastward at an angle of about 15° only. The breccia and conglomerate described here is greenish and gray, and is believed to lie at the actual local base of the Western border of the area.

Rocks near
Câche Creek.

formation. Further north, on the Bonaparte, where the line of junction was next clearly seen in detail, both the Palaeozoic rocks and the Cretaceous are nearly vertical, and faulting was suspected. That such faulting is probably not very considerable, is, however, indicated by the similarity of the beds of the Cretaceous here found near the contact, with the basal beds just alluded to. Still further north, on the west side of Câche Creek, just where that stream issues from the Tertiary escarpment into the wide Semlin Valley, gray Cretaceous sandstones were found dipping westward at an angle of 60°. They appear to rest unconformably on a gray, fine-grained and somewhat dolomitic limestone, which dips S. 45° E. to 45°. The limestone is associated with greenish schists and evidently belongs to the Câche Creek formation. It would appear that these old rocks came up on a small subsidiary fold or along the line of a fault, and that they form an isolated area within the main western edge of the Cretaceous.

Basal conglomerate
south-east of
Black Cañon.

On the east side of the Thompson, near the river, the rocks of the southern edge of the Cretaceous area are found to have a nearly east-and-west strike, dipping at high angles, apparently crushed against the older rocks in several folds, and very probably faulted. Further back from the river, a small projecting area of the Cretaceous was, however, observed, in which the beds are inclined at an angle of about 20° only, with varied direction of dip. The exposures, though not large, are of unusual interest, as they appear to represent the actual local base of the Cretaceous at this place in a little disturbed condition. The lowest bed, seen at one place, is a rough breccia, composed almost entirely of granitoid fragments of a single kind. This passes upward in a few feet, into a conglomerate with well rounded pebbles of the same kind, the change being gradual, and the cement in both cases calcareous. The conglomeritic bed rests in one place upon a green altered diabase near the junction of the latter with a granite mass. At another, it apparently rests upon the limestone described as the highest member of the section on page 113 B. Above, the conglomerate passes into gray sandstones.

TERTIARY ROCKS.

Kamloops Lake and Vicinity.

Information
embodied in
section No. 5.

The shores of Kamloops Lake were somewhat carefully examined in 1877, and some account of the rocks, together with a general section, were given in the report for that year. In connection with the more detailed investigations since undertaken, further examinations have

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been made, notably along the shores of the lake, but also in the neighbouring country. It was proved in 1877, that the best general section of the rocks is that afforded by the north side of the lake, the exposures being there more connected than elsewhere and the irregularity and disturbance of the beds less troublesome. The section now presented (Sec. No. 5) follows essentially the same line, and is based upon that of 1877, but with the addition of many new facts. It is now believed to represent, with proximate accuracy, the general structure and probable volume of the Tertiary and its component members in this vicinity.

It would appear, that the original surface upon which the Tertiary beds have been laid down, was generally lower in the vicinity of the present position of Kamloops Lake than elsewhere in this part of the region. This is shown in part by the greater thickness of beds referable to the lower portions of the Tertiary hereabouts, and by the occurrence in the neighbourhood of various members of that part of the Tertiary not elsewhere found. These features are very clearly seen, in examining the Tertiary rocks southward along the valleys of Watching Creek and the Tranquille River, or in approaching the lake shore, northward from the vicinity of Coal Hill. It is not, however, supposed that the original depression thus indicated corresponded either in extent or trend with that now occupied by the lake. Considerable changes in the relative heights of various parts of the old surface must since have occurred, as shown by the inclinations imparted to even the later beds of the Tertiary itself, while further differences of level have resulted from faulting at dates later than that of the Tertiary beds represented here. It appears, in fact, to be now quite impossible even to determine in what direction the drainage of this part of the country discharged previous to the disposition of the Tertiary rocks.

Original depression near Kamloops Lake.

A reference to the map will show that Cherry Bluff, on the south side of the lake, with Battle Bluff and its connected rocks on the north side, form two halves of what must originally have been a single mass of eruptive rocks and much altered greenstones. These are included under the colour employed for the plutonic rocks generally, though they differ considerably from the great granitic or dioritic masses, which more characteristically represent the plutonic rocks of the region. But in the case of these particular rocks, as well as in that of several smaller areas of a like character, it has been found to be impracticable, with our present knowledge, to draw a line of division between them and the granitic

Cherry and Battle Bluffs.

areas. They are closely associated with these, and resemble them also in regard to their relations with the older stratified rocks (see p. 246 B).

Their rocks.

The rocks of Battle and Cherry bluffs, consist chiefly of gabbro, diorite, mica-diorite and altered diabases-porphyrity generally, much decomposed and everywhere excessively shattered.* Epidote is abundantly developed in some places, and veins composed of magnetite, together with trap dykes of various kinds, frequently traverse the mass. The mass as a whole must be regarded as an intrusive one, or one which at least holds the same general relation to the older stratified rocks as do the granites, but it is probable that considerable portions of the older stratified greenstones have also become included in it and are now inseparable from it. On the north side of the lake, and resting on the north-west flank of the Battle Bluff rocks, there is, in fact, an area of hard purplish and gray diabases and diabase-tuffs still clearly referable to the Nicol's formation (p. 119 B).

Probably mark a vent.

A great part of the Battle Bluff and Cherry Bluff mass, above described, must be regarded as a portion of the floor upon which the Tertiary formations rest; but its position relatively to that of the Tertiary rocks, by which it is completely surrounded, with many other circumstances, appear to indicate also that it marks the site of a focus of volcanic activity of the Tertiary period. This was suggested in my report of 1877-78, and appears to be sustained by further investigation.

Original mass of volcanic accumulations.

The higher and central parts of the volcanic accumulations which may be supposed to have originated here, must have been situated directly above the middle of the present lake, but have since been removed by denudation, leaving now a proximately horizontal section of the old volcanic centre. There is, however, no reason to believe that the original volcanic cone was otherwise than obtuse in form, and, relatively to its area, low. The dips, (or slopes), of such of the peripheral volcanic beds as seem to have been least disturbed subsequently, show that it may never have attained a height of more than about 4000 feet above the present water-level of the lake.

Valley of the lake.

It is quite possible that volcanic explosions, or faulting and shattering of the rocks toward the close of the period of activity of this vent, may have assisted in producing the deep rift now occupied by that part of Kamloops Lake between Battle and Cherry bluffs. This must remain a matter of conjecture, but the position of the lake relatively to the old centre of eruption is a very remarkable one, and it is evidently in consequence of the formation of the hollow of the lake across

* See Appendix I, Nos. 96, 97, 99, No. 100 represents a stratified rock, caught up in the intrusive mass.

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the central part of the old vent, by some such exceptional circumstance, that the denudation of the volcanic cone has progressed from its central parts outwards, in a manner quite different to that seen in other cases.

It is also probable, that the old pre-Tertiary surface, including both stratified and eruptive materials, when it became penetrated and intersected in all directions by the deep-rooted channels of the Tertiary volcanic materials, was to some extent thrust upward in a dome-like form, giving rise to the nearly regularly oval slope of the present surface section.

Protrusion of basal mass.

Besides the actual position and form of the Battle Bluff and Cherry Bluff mass relatively to the volcanic beds of the Tertiary, further evidence of the existence of a centre of vulcanism at this place is afforded by the extremely shattered condition of its rocks, their exceptionally decomposed character, and the existence of such minerals as epidote and magnetite in considerable quantities in them, all pointing to the presence here of some exceptional cause of disturbance and of rock decomposition. Much of the last mentioned effect may have been produced by solfataric action subsequent to the main period of activity, and this appears to have been extended to the olivine rocks of the vicinity of Copper Creek, resulting in their change to serpentines and to the deposition of cinnabar and copper there. The great number of trap dykes seen in some places, as for instance along the lower part of the Tranquille River, may also be referred to in this connection.

Further evidence of a vent.

Reverting to the general composition of the surrounding Tertiary volcanic materials, additional evidence to the same effect is given by the great thickness of very coarse agglomerates or volcanic breccias, showing the recurrent action of local explosive forces, and the inclusion among them of flows of molten matter of various kinds. These rocks are well shown in the great escarpment to the north of Battle Bluff and in smaller exposures in Dufferin Hill, near Kamloops, and their inspection leaves scarcely any reasonable doubt that they actually represent parts of the flanks of a volcanic cone.

Great mass of coarse agglomerates.

The statement previously made respecting the existence of a depression in the vicinity of Kamloops Lake previous to the Tertiary period, cannot of course be maintained because of the exceptional thickness of beds of the character of those last alluded to, but depends chiefly upon the equally exceptional volume of evidently water-laid deposits chiefly formed of the finer volcanic ejectamenta.

The foregoing remarks on the general conditions of deposition of the Tertiary rocks surrounding Kamloops Lake, have been made in order

Succeeding description chronological.

to provide a clue to the geological features as a whole, and for the purpose of dispensing as much as possible with detail in what follows. The conclusions stated here result from much work in the field, as well as from the subsequent study of the specimens, notes and sketches accumulated, and if ultimately found to be subject to correction in some particulars, it is believed that they will in the main stand, although many additions may have to be made in future. It will now be possible to speak of the Tertiary rocks in chronological order, assembling in this way the observations made in various years, and over an extent of country some twenty-five miles in length by about ten in breadth. The older rocks, upon which those of the Tertiary period were deposited, will here be regarded together, merely as the floor upon which the latter lie.

Coldwater
group Oligo-
cene.

In a previous chapter of this Report, the several main subdivisions found to be applicable to the Tertiary rocks have been noted, and it has been pointed out for what reasons the lowest conglomerates and sandstones have been referred to the Oligocene, under the name of the Coldwater group, and are regarded as being separated by some lapse of time and unconformity from the lowest Miocene beds.

Basal con-
glomerates.

The lowest part of these conglomerates may be referred to as the basal conglomerate, merely for the purpose of convenience in describing its characters and supposed distribution. Rocks referable to the Coldwater group, are found only in certain parts of the area assigned to the Tertiary on the map, and even in these places the basal conglomerates are not always recognized and are sometimes clearly absent. These conglomerates are peculiar in the large proportion of material derived from the older rocks of the immediate vicinity in every case. They are generally dark-brown or greenish-gray in colour and vary much in the degree to which their constituents have been rounded by water action.

Conglom-
erates west of
Kamloops
Lake.

South of the Thompson River below Kamloops Lake, conglomerates of this character cap the lower hills for a distance of nearly eight miles. To the south they are in turn overlapped by Miocene volcanic rocks. They are here usually dark greenish-gray in colour, but often weather reddish. The pebbles are pretty well rounded, sometimes becoming boulders of as much as two feet in diameter, and comprising a considerable variety of greenstones of the underlying Nicola formation, as well as granitoid rocks of various kinds and some black cherty quartzites. With the conglomerates are gray and gray-green sandstones, moderately indurated, and in these some carbonaceous fragments were found at one place. The beds dip in various directions at low angles. They are often

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very well stratified and the whole thickness displayed in various places probably exceeds 500 feet.

A specimen of these basal conglomerates, holding large well rounded pebbles, on assay proved to contain traces of gold. The specimen was obtained from outcrops about one mile south of the Thompson River, opposite the mouth of Deadman River. Traces of gold.

It is very possible that a small area of conglomerates of the same kind, occurs at a nearly corresponding level on the hills due north of Penny station, on the opposite side of the Thompson. Large drift fragments were noted here, but the formation was not actually observed *in situ*. To the south of Savona station, no conglomerates of this kind could be found, the Miocene volcanic rocks apparently resting at this place directly on the Nicola formation.

A small exposure of similar conglomerates occurs on the road along Cherry Bluff Creek, between Roper's and Hughes's. A thickness of about fifty feet is here seen, extending from the level of the stream to where it is covered by a purplish porphyritic agglomerate, assigned to the Miocene period. Both rocks are very much fractured at this place. The stones in the conglomerate are more varied than usual in character and include a few specimens of cherty quartzite. They are well rounded and sometimes as much as a foot in diameter. The area of conglomerate exposed at this place appears to be small, but it is quite possible that more exposures of the same kind may occur in the wooded and generally drift-covered area to the west of this part of Cherry Bluff Creek. Conglomerates, Cherry Bluff Creek.

Crossing the lake to the north side, we find one of the most important developments of the Coldwater conglomerates and sandstones running back nearly parallel to Copper Creek for more than ten miles, with an average width of about a mile and a half. In the immediate vicinity of the shore, these beds appear to be overlapped and almost entirely concealed by dark greenish augite-porphyrates and agglomerates of the Miocene. But a single small mass of the conglomerates appearing from beneath these was seen on the shore, the beds dipping S. 45° E. < 60°, and themselves apparently resting upon rocks of the Nicola formation. Conglomerates and sandstones near Copper Creek.

There is much evidence of faulting and extreme disturbance in this vicinity and the details of the structure are by no means well understood. It is in fact supposed that several faults run nearly parallel with the belt of Coldwater beds, following their main strike, and in each case throwing the beds down to the eastward. It is probably in consequence of such faulting that the beds themselves are found to lie

at such high angles and to be sometimes even vertical. Such an effect is often seen in this region, even where the Tertiary rocks are generally undisturbed. The observed dips are in nearly all cases to the eastward, but towards the extremity of the formation, on Criss Creek, some westerly dips were noted and lower angles of inclination are more common.

From the above statements it will be gathered that the attempt to show the arrangement of the strata upon this part of the section is little more than diagrammatic and largely hypothetical.*

Cherty pebbles.

The conglomerate beds supposed to be the lowest in this place, show something of the same dark coloration and local character of material generally characteristic of those in that position. Higher up, and constituting the great mass of the rocks, are conglomerates with well rounded pebbles of moderate size and of light to dark gray or yellowish colour. With these are sandstones of similar tints, and both sandstones and conglomerates are preponderantly composed of cherty quartzites. These quartzites (evidently derived from the Cache Creek formation) are not known to occur in places in this neighbourhood, and their great abundance in the mass of the conglomerates, shows conditions markedly changed in comparison with those during which the basal conglomerates were formed, and in which the material was conveyed by rivers from a considerable distance and thoroughly rolled in transit. The local restriction of these characteristically cherty conglomerates as compared with the greater spread of those referred to as the basal conglomerates, further indicates a narrowing of the area of deposition after the period in which the lower beds of the series, regarded as a whole, were formed.

Traces of gold.

A specimen of these conglomerates collected near their western edge, on the trail north of Kamloops Lake, again showed traces of gold on assay.

Outliers on Garde Lafferty.

The identity of the cherty conglomerates of this locality with those of Hat Creek and the Nicola is elsewhere referred to. In all probability they here represent the delta or flood-plain of some early Tertiary river having its sources to the westward, rather than beds formed along the shores of a large lake, which appears to be the most probable origin for the basal beds generally. The total thickness of the Coldwater beds in this vicinity, is undoubtedly very considerable, and probably exceeds a thousand feet.

To the east of the main edge of the Tertiary rocks, in the somewhat peculiar tract of country named the Garde Lafferty, which occupies

* See also Section No. 1.

the angle between the North and South Thompson rivers, two small outliers referable to the basal conglomerates of the Tertiary are marked on the map. Other small patches of the same kind may occur in this vicinity, for the surface is often heavily drift-covered, and the known outliers show a tendency to characterize hollows in the contour of the older rocks. The conglomerate is here composed of rather small, well rounded pebbles, of all varieties of the older rocks, and includes a good many fragments of quartz derived from veins. There are also occasional thin layers of hard quartzose sandstone. The lowest layers of the conglomerates are highly charged with dolomitic matter, much indurated, and weather to reddish and yellowish colours. A similar dolomitization of the lower layers of the Tertiary rocks is found in a number of places in the district. It is here accounted for by the occurrence in the older rocks, of numerous veins of dolomite, which evidently mark the conduits by which dolomitic matter found its way to the surface at some time in the later Tertiary period. The basal conglomerates, though here found so near the main eastern outcrop of the Tertiary, have not been seen in actual connection with that outcrop; but the line of junction of the two series of rocks is almost always covered by debris from the bold escarpment of the overlying volcanic rocks of the Tertiary. It is probable that the conglomerates occur along the base of the Tertiary outcrops in the vicinity of Pass Lake and Lac le Bois. Further south, to the east of Mara Hill, the Tertiary finds its limit at a fault, with downthrow to the west.

Dolomitization.

A specimen of the conglomerate from the Garde Lafferty showed no trace of gold on assay.

In many other places in the vicinity of Kamloops Lake, various higher members of the Tertiary series, lie directly on the surface of the older rocks, by overlap. This is the case for instance to the south of Dufferin Hill and about the Battle Bluff and Cherry Bluff mass. It is probably also the case in the valley of Cherry Bluff and Alkali creeks; but this part of the southern boundary of the Tertiary is so poorly exposed that its position as laid down on the map is little better than conjectural.

Overlap of higher members of Tertiary.

It will be seen that the Coldwater beds, here almost exclusively represented by conglomerates, are very irregularly and partially distributed, even in the comparatively small area about Kamloops Lake. They are wanting in some places, very inconsiderable in thickness in others, but very thick in the vicinity of Copper Creek; these differences being due to original inequalities of the pre-Tertiary surface and to the positions of rivers and lakes antecedent to the beginning of the deposit of

General distribution and character of Coldwater beds.

the great mass of the Tertiary. They show no evidence of contemporaneous volcanic action, such *débris* of igneous rocks as they include being referable to the underlying Palaeozoic and Triassic strata. The beds here classed under this general term, may thus vary considerably in age, and some of them may represent a time long antecedent to the beginning of the period of Tertiary vulkanism. They are the traces of an epoch of erosion, which was in progress before the great period of Tertiary deposition had been inaugurated. The close resemblance of the cherty conglomerates of Copper Creek to those of Hat Creek, those of the Nicola near the mouth of the Coldwater and to those at a locality ten miles south of Nicola Lake (beyond the area of the Kamloops sheet), is, however, such as to lead to the belief that their deposit occurred synchronously and under precisely similar conditions (see p. 69 B).

Upper members of Tertiary.

The most satisfactory knowledge of the remaining members of the Tertiary series in the vicinity of Kamloops Lake, is that obtained by an examination of the sections about the eastern end of Battle Bluff and on the lower part of the Tranquille River.

As already mentioned, the coldwater Conglomerates (1) are here wanting.

Dolerite.

(2.) Resting directly on the flanks of the Battle Bluff mass and dipping away from it to the eastward and north-eastward at an angle of 15°, is a coarse gray dolerite, often regularly columnar and resembling a basalt, under which name it was noted in the report of 1877 (p. 117 B). This is 100 feet or more in thickness.

Tuffaceous beds.

(3.) Above the last, is a series of yellowish and bluish-gray, hard, thin-bedded and fine-grained tuffaceous shales and shaly sandstones. These hold numerous fragments of plants in a very poor state of preservation and some obscure fish remains were also found in them. The thickness of these beds is probably more than 200 feet near the lake shore, but their outcrop appears to narrow rapidly when followed north-westward and westward along the strike, till it disappears. This particular intercalation of water-bedded material was not certainly recognized elsewhere, though it is possible that it may recur in some part of the broken section along the south shore of the lake between the eastern end of Cherry Bluff and the head of the lake. It is probably quite local, and may represent the position of a small lake, held in for a time by the growing volcanic accumulations of the vicinity.

Dolerites and tuffs.

(4.) Overlying these stratified materials, are more dolerites, coarse grained at the base, but finer in the upper layers. These probably represent a series of flows of molten matter, and are arranged in beds of varying thickness, some of which are finely columnar. The thick-

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ness represented by these flows at this place is at least several hundred feet and very probably as much as 1000 feet, in all. The strictly igneous flows constituting this series, pass above into water-bedded tuffaceous sandstones, largely composed of doleritic debris, in such a manner that it is difficult to draw a distinct line of division between the two classes of rocks.

(5.) The tuffaceous sandstones last mentioned, together with yellowish tuffaceous agglomerates, of which the material appears to be largely doleritic, constitute the next number of the section, with a thickness of at least 500 and probably of nearly 1000 feet. These appear, with dips of 10° to 15° to the eastward, where the Tranquille River issues from its narrow valley to the head of its delta-flat, at a distance back from the lake-shore of about half a mile. A short distance further eastward, they flatten out, and run along the southern face of Mara Hill, near the line of the wagon-road which leads from Tranquille to the ferry at Kamloops. These beds, representing an important interval in which volcanic materials were being laid down in the waters of the lake, have been named the *Tranquille beds*. Tranquille beds, Tuffs and agglomerates.

In the stratified materials of this subdivision, small collections of Fossil plants. plants have been made from the lower part of Tranquille River by Mr. A. Bowman, and from corresponding beds on the south side of Kamloops Lake (those at the east end of Section No. 5a.,) by the writer. In these the following have been recognized by Sir J. Wm. Dawson. *

Pinus trunculus, Dn.

Taxodium distichum, Heer.

Ailanthophyllum incertum, Dn.

Comptonia Columbiana, Dn.

Salix Kamloopsiana, Dn.

Ulmus like *U. Braunii*, Heer.

Sequoia, Sp.

Imperfect remains of fishes have also been found in these beds in this vicinity.

(6.) Overlying the last, and apparently not separated from that division of the section by any distinct line, is a great thickness of materials predominantly basaltic, consisting of brownish, blackish, gray and reddish basaltic agglomerates with occasional basaltic flows, which are, however, rarely columnar. The bedding of this series is rather massive and irregular, and the component beds are often lenticular, though from a distance the aggregate presents the appearance Basalts and basaltic agglomerates.

*Trans. Royal Soc. Can., vol. VIII., sect. IV., p. 75.

of a regularly stratified formation. The upper part, which is here the highest member of the Tertiary, shows a preponderance of rather soft, yellowish-gray agglomerates of a tuffaceous character. The component fragments though often vesicular, are frequently dense black trachytic material with the fracture of obsidian. The observed thickness of this highest member of the series is here about 2000 to 2500 feet.

Thickness.

The entire thickness of Tertiary beds displayed in this vicinity, may thus be stated at about 4800 feet.

Distribution
of lower sub-
divisions.

Having described the section in this typical locality in some detail, it will now be in order to endeavour to trace the occurrence of its various members throughout the county in the vicinity of Kamloops Lake. For this purpose the local stratified intercalation designated as No. 3, may be disregarded, and the dolerites, forming numbers 2 and 4, may be considered as a unit. These rocks run round to the north of the central Battle Bluff mass for some miles to the westward, and were in some places observed to become concretionary in structure. They were not found at the western end of the older central mass, where the next overlying and bedded series (No. 5) seems to overlap directly on the rocks of the Nicola formation (p. 158 *u*) which are here attached to the Battle Bluff rocks and may be considered structurally as forming a part of that older mass.

How repre-
sented at
Copper Creek.

Still further west, beyond a wide syncline occupied by the rocks of subdivision No. 6, the older members of the Tertiary series again reach the surface near Copper Creek. The dolerites appear here to be represented by igneous rocks rich in olivine, of the character of picrite-porphyrates and by augite-porphyrates, which so far as can be ascertained immediately overlie the cherty conglomerates previously described, and intervene between them and certain bedded materials, which are believed to represent No. 5 of the typical section, with a thickness of possibly about 600 feet. One of the olivine bearing rocks, where comparatively unaltered, has been determined by Mr. Ferrier to be an augite-picrite-porphyrate.* These rocks, together with the overlying bedded materials largely derived from their waste, have, in the vicinity of Copper Creek, suffered a remarkable amount of decomposition and change due to solfataric or hydrothermal action operating from below, and probably connected with the excessive faulting and fracture met with at this place.

Painted
Bluffs.

The Painted Bluffs, on the east side of Copper Creek, are composed of these much decomposed rocks, apparently including parts of the

*Appendix I., No. 67.

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overlying bedded series No. 5. Green, yellow and red colours prevail in the sloping and clay-like banks of rotten rock, amongst which rounded masses, and irregular layers of the undecomposed trap still exist. The olivine has become in many instances completely changed to serpentine in the decayed rock, while the felspars are more or less completely kaolinized. The whole section is traversed by dykes and by many small veins and seams of calcite.

Near the mouth of Copper Creek, on the lake, portions of the beach are largely composed of green sands, consisting for the most part of more or less worn small crystals of pyroxene. The nature of the alteration suffered by the olivine rocks at this place is fully described by Dr. B. J. Harrington in the Report of the Geological Survey for 1877-78, p. 41 a. The occurrence of cinnabar and of copper in connection with these rocks in this vicinity is elsewhere noted. Mineral occurrences.

A reddish brecciated rock, with greenish markings and cavities and well developed green hornblende crystals, which appears to lie near the base of the section above described, close to Copper Creek, was, it is believed again recognized on the lower part of Cherry Bluff Creek, on the opposite side of the lake, adjacent to the Cherry Bluff rocks and dipping off them. Some serpentinous and olivine-bearing rocks were also seen in the valley of this stream, and it is probable that rocks representing the part of the section now under discussion occur here, possibly in some force, but no good exposures of them have been found. Cherry Bluff Creek.

Opposite the typical section of the Miocene Tertiary rocks first described, on the south side of Kamloops Lake and to the east of Cherry Bluff, dolerites referable to No. 4, and possibly in part to No. 2, are seen in several places along the shore (Sec. No. 5a.). They also run round behind the rocks of Cherry Bluff more or less continuously, and at one place, a short distance south of the word "Bluff," as engraved on the map, are so coarsely crystalline and massive as to suggest the idea that they represent the place of an actual source of emission. Rocks east of Cherry Bluff

The stratified tuffaceous sandstones designated as the Tranquille beds (No. 5) probably run continuously round behind the Battle Bluff rocks on the north, following a hollow along the base of the higher cliffs and hills further back. They reappear on the lake shore near Red Point, with a breadth of about a mile; being thrown into a couple of light synclines and traversed at Red Point itself by a small fault. At this place, or very near it, a small bed of lignite was found during the progress of the Government railway surveys in 1878. The sandstones are here yellowish and gray, like those near the Tranquille. Distribution of Tranquille beds.

Their further outcrop is concealed by the lake, till they reappear in the Painted Bluffs near Copper Creek, where, as already explained, they are much altered and generally reddened.

East of
Cherry Bluff.

To the east of Cherry Bluff, the same tuffaceous sandstones are found in several places, associated with the dolerites already alluded to, but the section (No. 5a) is here so much broken that it has been found impossible to satisfactorily unravel it with the information available. The widest and least disturbed exposures of these sandstones and shales here met with, are near mile-post 244 on the railway, where they dip northward at an angle of about 20° , and where a few fossil plants were found. It is believed that these beds run from this place inland, in an easterly direction, following the hollow along the south base of Dufferin Hill, and that they connect with those of the coal locality near Guerin's, where they terminate in a feather edge upon the underlying old rocks, at a point about three miles due south of the town of Kamloops.

Coal-bearing
rocks south of
Kamloops.

The exposures are not continuous along the line of outcrop thus traced, but there can be little doubt that the beds associated with the coal at Guerin's represent the Tranquille beds (No. 5) of the general section. These particular beds, where found near Guerin's, require special mention, because of the interest consequent on the discovery of coal in them, and the fact that some exploratory work has been carried out in the search for workable seams. The beds containing the coal here rest directly upon the pre-Tertiary surface, by overlap, the underlying members of the Tertiary being absent. The floor consists of a rough surface of diabase-agglomerates, upon which the Tertiary materials lie in the form of a shallow syncline which runs along the northward slope of Coal Hill. The exposures are almost entirely confined to the banks and bed of the small stream which flows past Guerin's house, and even with the aid of information obtained in the course of driving an adit into the measures, give but an imperfect idea of the section. The actual area of this projecting tongue of the Tertiary is shown on the map as closely as the facts observable on the ground admit. Its width is somewhat less than a mile—probably not more than three-quarters of a mile, while the thickness of the measures comprised in the syncline may be as great as 500 feet, but is possibly much less. The beds actually associated with the coal outcrops which have been uncovered, dip N. 25° W. $\angle$ 38° , but probably flatten out to the northward and take the position shown in the annexed section. The measures, so far as exposed, consist of greenish and yellowish tuffaceous and agglomerate-like materials more or less distinctly bedded, which weather to soft clayey

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The section
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Shale..
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Shale..
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* From Sun

stuff, often reddish in colour. There are several thin layers of good coal, varying from mere films up to a foot in thickness, and characterizing in all about fifty feet thick of the measures.



Fig. 2. SECTION INCLUDING COAL, NEAR KAMLOOPS.

The line of section is about north-east and south-west, passing through Guerin's house. The Miocene beds containing coal (division No. 5) are shown overlying rocks of the Nicola formation, indicated by the oblique parallel lines. Scale 2 m. = 1 inch.

The beds with which the coal is associated, undoubtedly pass under the basaltic agglomerates composing Mount Dufferin, to the northward, and if the coal should be found to occur there in workable thickness, this would prove a more eligible field for exploration than that to the southward of Guerin's, even if the coal beds of the last-mentioned locality were much thicker than any yet developed.

In 1892, the locality of the coal occurrence near Guerin's was again visited by Mr. J. McEvoy. At this time an incline was being sunk on the dip of the beds, which eventually reached a depth of from seventy to eighty feet, but without showing any marked improvement in the character of the seams.

The section including the coals, as then seen, was as follows, in descending order* :—

	Inches.
Coal.....	3
Shale.....	5
Coal.....	12
Clay.....	4
Coal.....	2
Shale.....	6
Coal.....	3
Shale and clay.....	5
Coal.....	5
Shale and sandstone.....	12
Coal.....	2½
Sandstone.....	8
Coal.....	3

* From Summary Report of the Geological Survey for 1892, p. 10.

The quantity of clay is variable and some of the shale partings are not continuous. The aggregate thickness of coal at this place is 30½ inches.

Further tests required.

The fuel found here is a true coal rather than a lignite, burning well and producing a coherent coke. If in seams of really workable thickness, it would possess considerable economic importance. To ascertain definitely whether any thicker seams occur at the locality near Guerin's, it would be necessary to sink or bore vertically through the measures, near the position of the present openings, till the subjacent diabase rocks are reached. The depth required cannot be great. Little further information can be hoped for in following the thin seams already found.

Places recommended for boring.

The whole area of possibly coal-bearing rocks in this vicinity is, however, so small, that it would appear to be better worth while to test the general question of the occurrence of coal in this neighbourhood by putting down one or more borings in places where the same subdivision of the Tertiary series has a greater development. The sites which seem to be most promising for this purpose with our present knowledge of the structure, are the following:—

Near the 244th mile-post on the line of railway or within half a mile east of that point on the line.

Tranquille River, on the east side, in the flat near the point at which the irrigation ditch is taken off and just below the mouth of the narrow cañon-like part of the valley.

A third locality might be selected about two miles east of the Tranquille River between the wagon-road and the base of the steep hill above it.

If no good seam of coal should be found in any of these places, it would be pretty conclusively proved that none exists in this vicinity, if, on the contrary, such a seam were discovered, the question might arise of tracing its extent elsewhere in the neighbourhood of Kamloops Lake, where further suitable sites for boring could be determined with the aid of the section which accompanies this report.

The occurrence, near Drooping-water Creek, of beds probably of the same age with those holding the coal at Kamloops, is described on a later page (p. 234 B). There also small quantities of coaly matter, with fossil leaves, have been observed. The two areas of deposit were, however, probably isolated, as the basalts of the intermediate country appear to rest directly upon the granites.



Fig. 3. PART OF THE NORTH SIDE OF KAMLOOPS LAKE, SKETCHED FROM THE MOUTH OF CHERRY BLUFF CREEK.

The parts vertically ruled consist of the plutonic rocks of the Battle Bluff mass, with, to the west, an attached area of Nicola rocks. The higher hills behind, consist chiefly of the basaltic member (No. 6) of the Miocene, forming an escarpment. Apparent dips from the point of view chosen, are indicated by the inclination and length of the arrows.

Escarpment of
subdivision 6.

The highest of the Tertiary series in the vicinity of Kamloops Lake, described as No. 6 in the general section, has a notable effect in giving form to the topography of the district. It consists in the main of rough basaltic agglomerates and basalt flows, which have a tendency to form steep, rugged cliffs where the outcropping edges are worn away. A remarkable and continuous range of high, bold cliffs and escarpments, encircles to the north the lower hilly country occupied by the Battle Bluff rocks and the lower members of the Tertiary. This runs, with a curving sweep, from the vicinity of the Tranquille River to that of Red Point and then up the valley of Copper Creek. Similar escarpments occur along the main valley of the Tranquille, on both sides, at least as far up as the position of the waterfall shown on the map. The upper parts of Mara and Opax hills are formed of rocks of the same series, which are again well shown to the south of the lake, in Dufferin Hill.

Section in
Savona
Mountain.

Elsewhere to the south of the lake, these higher rocks have apparently been almost entirely removed by denudation, except in Savona Mountain. The summit of this mountain stands about 3700 feet above the level of the lake. It was ascended on the north side, and notes obtained upon which the annexed section is based. The lower and upper limit of each stratum could not in all cases be ascertained in such a manner as to enable its precise thickness to be stated, and the beds themselves evidently vary much in this respect in short distances, so that the section must be considered as more or less diagrammatic, although giving a sufficiently correct idea of the general



Fig. 4. SECTION FROM SAVONA STATION TO THE SUMMIT OF SAVONA MOUNTAIN.

Miocene volcanic rocks overlying those of the Nicola formation. Letters refer to the description in the text. Scale, 2 m. = 1 inch.

Character of
rocks.

sequence. The lowest bed (a.) which apparently rests on the pre-Tertiary floor of diabases, felsites, etc., of the Nicola formation, is a gray somewhat vesicular basalt. This forms a distinct escarpment of 200 or 300 feet in height. Overlying this is a gray laminated trachyte (b) containing some small mica crystals, of which the thickness was not

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ascertained or agglomerate least one bed. The great beds of trachyte (d). The trachyte has a thick mountain mass of near

The fragments and their matrix consists entirely of diabase-like material holds somewhat friction in the matrix is an agglomerate to wear out which has some basalts in some greenish in

The entire may be referred thickness is the fragments appears to eruption. are continuous they form

Recapitulation and giving the several all present

No. at in

* Appendix

ascertained. This is succeeded by a great thickness of volcanic breccia or agglomerate (c), including near its summit, on the line of traverse, at least one bed of brownish, more or less distinctly laminated basalt (a). The great agglomerate bed is followed in order by comparatively thin beds of trachyte (b), vesicular basalt (a), and a gray, obsidian-like rock (d). The trachyte has been determined by Mr. Ferrier to be a mica-trachyte with a tendency toward andesite.* The obsidian-like layer has a thickness of about 100 feet. Above these, the summit of the mountain is composed of a second great agglomerate (c), with a thickness of nearly 1000 feet.

The fragments composing both agglomerates are generally large, ^{Coarse} ^{agglomerates.} and their material differs much in character, but so far as observed consists entirely either of igneous rocks referable to the Tertiary or of the diabase-like rocks of the older Nicola formation. The upper agglomerate holds masses as much as six feet in diameter, which are generally somewhat rounded, but not more so than may be accounted for by friction in the vent from which they must have been expelled. The matrix is a gray tuffaceous material often resembling mortar. This agglomerate forms cliffs near the summit of the mountain, tending to wear out into pinnacles, each capped by one of the larger fragments which has served as a protection from the action of the weather. The basalts in some places hold numerous agates, which are often green or greenish in colour and sometimes very handsomely marked.

The entire series of beds included in the Savona Mountain section ^{Thickness.} may be referred to No. 6, of the general section. Their aggregate thickness is about 3000 feet. The great size of a large proportion of the fragments here, together with the thickness of the agglomerates, appears to indicate the immediate vicinity of some local centre of eruption. The same beds seen on the north side of Savona Mountain, are continued southward along the west side of Three-mile Creek, where they form bold and picturesque cliffs.

Recapitulating the general section of rocks about Kamloops Lake, <sup>Recapitul-
ation of Kam-
loops Lake
section.</sup> and giving to each member its probable maximum thickness, the following scheme may be presented. It will, of course, be understood that the several subdivisions vary much in thickness, and are moreover not all present in any single place. The order is descending.—

	Feet.
No. 6. Agglomerates, chiefly basaltic, with some basaltic and trachytic flows; all rudely bedded. Thickness in Savona Mountain.....	3,000

* Appendix I., No. 68.

	F ^{et} .
No. 5. Tranquille beds; tuffaceous sandstones and shales, with some soft tuffaceous agglomerates, all more or less distinctly water-bedded; holding occasional plant remains, fragments of fishes, carbonaceous matter and in some places coal. Thickness near Tranquille River, about.....	1,000
No. 4. Doleritic rocks, representing flows of molten matter. Thickness near Tranquille River about.....	1,000
No. 3. Tuffaceous shaly beds, generally in thin layers, holding obscure plant and fish remains. Local thickness near east end of Battle Bluff.....	200
No. 2. Dolerite, like No. 4. Thickness near east end of Battle Bluff, at least,.....	100
No. 1. Coldwater group; conglomerates composed of pre-Tertiary material, with some sandstones. Very irregularly developed and often wanting. Probable thickness near Copper Creek about.....	1,000
	6,300

Diagrammatic
Section No. 5.

Boss of
crushed
granite.

The section (No. 5) in which an endeavour is made to show the general features along the north shore of Kamloops Lake, after the details above given, scarcely requires further explanation. The synclinal form which the old rocks below the Tertiary are represented as holding at the west end of the section, is to some extent conjectural, as it is scarcely possible to determine the attitude of these beds here. It is based in part on observations made between Deadman River and Copper Creek, at some distance back from the lake, in part on the fact that a limestone, assumed to be the same with that seen on the lower part of the Deadman, must outcrop near the western edge of the Tertiary conglomerates here. This is rendered evident by the notable abundance of limestone in some of the Tertiary conglomerates or breccias at this place. It is further confirmed by the occurrence of limestone approximately on the presumed line of strike on the opposite side of the lake. That part of the section of Tertiary rocks to the west of Copper Creek, must be regarded as scarcely more than diagrammatic. Just east of Copper Creek, on the lake shore, a low hill occurs composed of a crushed granitic rock, which is common with the neighbouring Tertiary rocks, is excessively decomposed. It shows in places minute specks of cinnabar. It is uncertain whether this is an original projecting boss of the pre-Tertiary floor, or whether its appearance at the surface is partly due to faulting; but it is noteworthy that a couple of similar isolated granitic masses occur some miles to the north-westward of the lake in the continuation of the general line of the Copper

Creek Valley to this valley.

The faulting on the shore there is interesting, how are occasional very high Copper Creek a similar mass believe that unconformable.

The overlying upon the pre-Tertiary depends on the from the shore not closely connected.

As the up lake, it does higher hills Tranquille River features of the east of the Tertiary Mara Hill, and

The intrusion are not accurately abundance of

It has also south shore of Cherry Bluff the exposure of small faultward. The shore, will show way, as the known. Inward of about as coming in Dufferin Hill the town of

Creek Valley. The main direction of faulting probably runs parallel to this valley.

The fault shown at Red Point, is very distinctly seen on the lake shore there, but its throw is in all probability quite small. It is interesting, however, in illustrating the manner in which the Tertiary beds are occasionally, and very locally turned up at high angles. The very high dips frequently found in the conglomerates to the west of Copper Creek, are supposed to have been produced for the most part in a similar manner, though as elsewhere explained, there is reason to believe that these conglomerates are considerably older than, and lie unconformably below the other Tertiary rocks (p. 69 B).

Fault at Red Point.

The overlap of the stratified rocks of the Tranquille series (No. 5) upon the pre-Tertiary surface, shown to the east of Red Point, depends on the examination of the line of junction nearly a mile back from the shore of the lake. On the shore, this part of the section was not closely examined.

Other data embodied in section.

As the upper line of the section is drawn at the water-level of the lake, it does not indicate the connected escarpment formed in the higher hills inland, by the rocks of No. 6, between Red Point and the Tranquille River. This is, however, one of the most prominent features of the north shore of the lake as seen from a distance. To the east of the Tranquille, the same rocks form the high plateau-like top of Mara Hill, and rest there upon the nearly horizontal beds of No. 5.

The intrusive dykes as represented near the east end of Battle Bluff, are not accurately laid down, but are intended merely to indicate the abundance of such dykes.

It has already been explained that the section furnished by the south shore of the lake is very imperfect, particularly to the west of Cherry Bluff Creek. To the east of the massive rocks of Cherry Bluff, the exposures are much better, but they are complicated by a number of small faults, which appear to throw the strata down to the westward. The partial section (No. 5a.) given for this part of the south shore, will serve to indicate its general character, but in a diagrammatic way, as the positions and number of faults are very imperfectly known. In this part of the section, a total downthrow to the westward of about 1000 feet may easily occur. The basaltic rocks shown as coming in at the east end, are the lower parts of those which form Dufferin Hill, which is situated about three miles to the westward of the town of Kamloops.

Section 5a.

Section of Tertiary Rocks along the Nicola Valley.

Nicola Section, No. 7.
Data employed.

After the sections about Kamloops Lake, the most instructive general section so far obtained is that along the Nicola River. In 1877, a paced survey was made along the Nicola Valley, from the mouth of the river as far up as the confluence of the Coldwater, a distance of about forty miles. This examination was undertaken for the purpose of obtaining a section of the Tertiary rocks exposed along the valley, and with reference particularly to the extent and mode of occurrence of the coal deposits which had for a number of years been known to exist near the mouth of the Coldwater. It was conducted chiefly along the wagon-road which follows the valley, and allusion is made to the result obtained in the report for 1877-78 (pp. 127 B, 128 B). As a whole this result was disappointing, for the information gathered proved to be insufficient for the explanation of the section. When a re-examination of this part of the country was undertaken in 1888 and 1889, additional facts were sought for along the Nicola Valley, and in its vicinity on both sides. These have now been added to those previously obtained, and a careful reconsideration of the whole has been instituted, from which the section appended to this report results. (Section No. 7.)

Degree of accuracy obtained.

While this is believed to be at least approximately correct in its main features, it must be stated that the explanation given of many of the observed facts in detail on the section, is still more or less hypothetical. The probable existence of undetected faults of small throw, is the most important element of uncertainty, but the massive character of the beds and the general absence of clearly recognizable horizons of a continuous character, render it very difficult to prove faulting even where it is suspected. It would undoubtedly be possible, by the expenditure of sufficient time and the extension of surveys to a belt of country several miles wide on both sides of this part of the Nicola, to produce a section accurate in all its details. The section here offered is, however, sufficient to indicate the general attitude of the rocks in a broad way, and will be found of value in connection with the question of the possible extension of the coal-bearing rocks (Coldwater group) which occur at the surface near the confluence of the Nicola and Coldwater and at Guichon Creek.

General features.

Omitting from consideration here, the sandstones and shales of the coal-bearing locality just alluded to, respecting which some remarks are made on a later page, the composition and general structural features of the Tertiary rocks in the vicinity of that part of the Nicola included in the Kamloops sheet, are sufficiently clear. The series may here be described as consisting of two great divisions

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separated soft and believed to which the is in consequence to be confirmation, has been it is a granular as porphyritic fresh appearance often so massive usually present the Tranquility generally of

The volcanic are sometimes constituting of the two so that no

In regard whole is bound appears to be west side. The side. The along it, bed materials are the porphyritic above alluded. The lowest about this

At or near high angles, has a low series of small tra lows a line about three of the outer be traced materials. the line of and recross

separated by a horizon characterized by certain pale-coloured, often soft and frequently well-bedded tuffaceous materials. These are believed to correspond with the very similar beds on Kamloops Lake, to which the name Tranquille beds has been applied, and the same name is in consequence extended to them. This horizon, which appears to be continuously represented throughout the length of the section, has been employed as the principal clue to its intricacies. Beneath it is a great thickness of volcanic rocks, chiefly to be classed as porphyrites. These are sometimes distinct augite-porphyrates, of fresh appearance in regard to their mineral constituents, but are often so much decomposed that, though the porphyritic structure is usually preserved, it is difficult to name them with precision. Above the Tranquille beds is another great mass of volcanic rocks, consisting generally of basaltic materials.

Tranquille
beds.

The volcanic rocks of both the upper and lower parts of the series are sometimes clearly effusive, but perhaps more frequently fragmental, constituting agglomerates or volcanic breccias, and the rock species of the two parts of the series are not altogether mutually exclusive, so that no strict line of lithological division can be drawn between them.

Upper and
lower divi-
sions.

In regard to the general structural features, the Tertiary series as a whole is bounded to the north-east, in this region, by a line which appears to be that of a continuous fault, with downthrow on its south-west side. This follows the edge of the great granite mass on that side. The line of faulting runs about N. 35° W., by S. 35° E., and along it, beds of tuffaceous sandstones and other water-bedded volcanic materials are found in several places. These are believed to underlie the porphyrite rocks and to be quite distinct from the Tranquille beds above alluded to, although denoted by the same colour on the map. The lowest rocks seen near the mouth of the Nicola seem to be at about this horizon.

Great fault to
north-east.

At or near the fault, the Tertiary rocks are often found inclined at high angles, or even vertical, but the series as a whole, in this region, has a low south-westward dip, upon which are superimposed a number of small transverse undulations. In the main, the Nicola Valley follows a line parallel to that of the fault, at an average distance of about three miles and a half from it. This line is approximately that of the outcrop of the Tranquille beds, and the position of the river may be traced to the existence of these softer and more easily eroded materials. In detail, however, the undulations just alluded to throw the line of outcrop of these beds into a series of zigzags, which cross and recross the actual line of the river. The beds themselves show

Relation of
Nicola Valley
to Tranquille
beds.

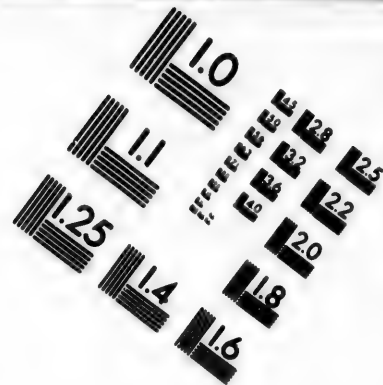
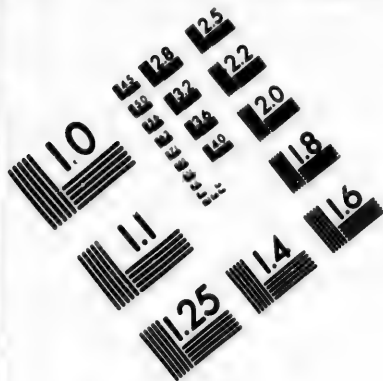
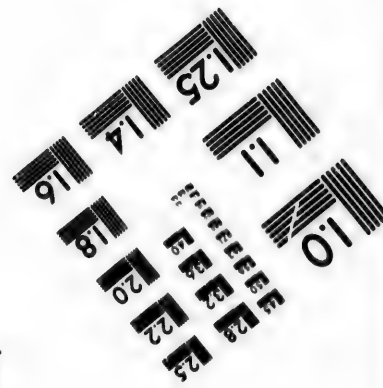
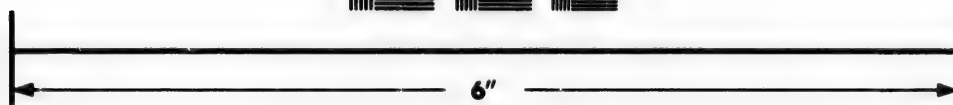
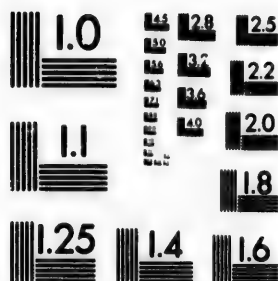


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a tendency to pass into tuffaceous agglomerates of a more or less earthy character, and in which it is often scarcely possible to make out any stratification. It is thus generally difficult to ascertain their thickness, even when the sections are good. To the south-west of this part of the Nicola Valley, is a wide syncline, occupied chiefly by the basaltic rocks of various kinds which overlie the Tranquille beds. These rocks form the Nicoamen Plateau of the map.

General composition of series.

Thus, so far as the composition of the Tertiary series in this region has been determined, it is made up as follows, in descending order:—

	Feet.
Basalts, basalt breccias, etc. (about).....	3,100
Bedded tuffs (Tranquille beds) (")±.....	500
Porphyrites, etc. (about).....	5,300
Total.....	8,900

Subdivision of Section No. 7.

In the following more detailed descriptive notes on the Tertiary rocks found along the valley of the Nicola, the section is divided into five parts, each of which follows one of the minor trends of the valley, and though the section may be described as a whole, as running from north-west to south-east, it has been found convenient to change the direction in each case to correspond with that of the general bearing of a certain length of the valley. On the annexed diagrammatic section, these changes in direction are clearly indicated.

Part 1.

Part 1.—This extends from the mouth of the river in a direction S. 40° E., to a point one-half mile above the confluence of the first small stream from the north-east, with a total length of about six miles.

Oldest rocks.

The lowest rock met with, is that seen less than a quarter of a mile above the bridge by which the wagon-road crosses. It is a gray amygdaloidal material of a rather soft tuffaceous character, apparently nearly flat, and very probably forming the summit of a gentle anticlinal swell. Beyond this, in ascending the valley, most of the beds comprised in this part of the general section have southerly dips at angles of 30° or less. The valley crosses the outcrops obliquely, and the series is in the main an ascending one. From this general rule there are, however, two exceptions. At about two miles up the river, the beds are found to flatten out and to run nearly horizontally for about a mile further. Again, for nearly a mile at the end of this length of the section, the beds become undulating and are in the main not far from horizontal.

Newer rocks in ascending valley.

The general effect of the attitude of the beds is, however, that newer strata are found in order in ascending the valley, and the whole thickness thus exposed, to the base of the Tranquille beds, which form

the highest member here seen, is about 5300 feet. Of this the lower part, some 3100 feet, consists, so far as seen, of reddish, blackish and greenish volcanic rocks, often brecciated, occasionally vesicular, and in general to be classed as porphyrites of various kinds. An important bed of greenish, somewhat earthy, tuffaceous agglomerate or volcanic breccia then appears, which, with various volcanic rocks of green, gray-green and dark colours constitutes the next 2200 feet in thickness of the section. As before, these rocks are in the main porphyrites. These are followed in ascending order by well bedded tufts or tuffaceous sandstones, apparently entirely composed of fine-grained volcanic materials, which have been arranged in regular layers of water. No complete display of this member of the section was seen, but it was noted to be at least 130 feet in thickness, and it may very considerably exceed this. These stratified tufts are referred to the horizon of the Tranquille beds.

Part 2.—This connects with the last, and runs in a direction of S. 30° E. to the mouth of Skuh'un Creek, a distance of exactly six miles. It is the least satisfactory part of the entire section, inasmuch as the main direction of the dip of the beds is south-westward, and the line of section consequently nearly follows the general strike. It is further complicated, near the mouth of Skuh'un Creek, by several rather pronounced subsidiary flexures and possibly by some faulting. This part of the section can thus only be regarded as a connecting link, in which the beds are shown to lie in a position approximately correct. In the main, the river coincides with the outcrop of the Tranquille beds, crossing and recrossing it. The line upon which this part of the section is projected, lies a little to the north-east of the corresponding length of the river, and consequently to the eastward and stratigraphically below the greater part of the sinuous outcrop of these beds, which are more persistently represented along the river itself than the section indicates.

Outcrop of
Tranquille
beds.

No great thickness of rocks is clearly seen in this length of the section, but here, as in the first part, the material immediately underlying the Tranquille beds is a hard greenish or green-gray porphyrite. The water-bedded materials are greenish, pale gray and brownish in colour and generally fine-grained, but they pass in places into greenish tuffaceous breccias of earthy fracture, which do not show any distinct evidence of deposition in water. In one place, a mile and a half below Skuh'un Creek, the well bedded materials were observed to be directly overlain by a blackish obsidian-like rock, probably a fine-grained augite-porphyrityte.

Basalts.

The highest dips, observed locally, are at angles of 20° to 30° , while considerable parts of the formation appear to be nearly horizontal. The mountains along the south-west side of the valley seem to be almost entirely composed of massive basalts and basalt-breccias, with a general low westerly dip, but showing some light transverse undulations in their outcrops.

In the part of this section nearest to Skuh'un Creek, beyond the last outcrop of tuffaceous sandstones in that direction, the attitude given to the beds is little more than conjectural, having been made to agree with the adjacent end of the next length of the section. A considerable thickness of the lower part of the formation must either come to the surface in the way indicated, or a corresponding change of horizon must be produced by faulting, with a downthrow to the north-westward, of which no direct evidence was observed.

Part 3.

Part 3.—This extends from the mouth of Skuh'un Creek to the vicinity of that of Smith's Creek (the next small stream from the north-east) in a bearing of S. 43° E., and is about four miles and a half in length. Comparatively little is seen of the rocks near the wagon-road, which run for the most part along terraces at some distance from the river, in this part of the valley. The rocks are, however, almost continuously exposed along the river itself, and were somewhat carefully examined on the south-west side of the river. From a point about three-quarters of a mile above the mouth of Skuh'un Creek, the section appears to be, for two miles and a half, continuously an ascending one, with south-easterly dips averaging perhaps 30° and sometimes rising to 40° . A better idea of the constitution of the Tertiary volcanic series was gained here than elsewhere in the valley.

Rocks chiefly porphyrites.

The rocks consist for the most part of porphyrites, probably all originally augite-porphyrates, but often much decomposed. It is perhaps impossible to draw very definite lines between the different component strata in all cases, even if the information available were much more detailed than it is, but the general character of the materials may be indicated as follows, in ascending order.

Series in ascending order.

The lowest beds seen, appear, as already stated, to be those at about three-quarters of a mile above the mouth of the Skuh'un, where an antichlinal axis is supposed to cross the Nicola. These are gray-green porphyrites and greenish-gray porphyritic agglomerates, of which the felspathic constituents are almost entirely decomposed, giving the rocks a dull speckled appearance, and in some of which newer crystals of zeolitic minerals have been developed. These are followed by dark

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greenish, bluish and dull purplish porphyrites, the latter preponderating, generally much fresher and with clearly defined felspar crystals.* Above these, just below the mouth of a small stream which enters from the south-west, is a gray augite-porphyrte, with a isolated appearance, due to lines of flow-structure in its mass.† Next in order is a red, rusty, shattered felspathic rock, now scarcely determinable, followed by a dark greenish-black porphyrite in which some fragments of coarse gray gabbro were observed to have been caught up. This is succeeded in turn by much decomposed purplish porphyrite,‡ grayish porphyrite, reddish porphyrite-agglomerate and dark greenish-gray, fine-grained, much decomposed porphyrite with flow-structure.

Next in order are the Tranquille beds, which here form a syncline near the south-eastern end of this part of the section. They consist, in great part, of well-stratified, fine-grained rocks of gray and yellowish-gray colours, usually pale and sometimes much indurated, resembling felsites; but also pass into coarse clastic and agglomerate-like tuffs, between which and the finer and more regularly bedded materials it is often difficult to draw any precise line. In the centre of the syncline and overlying these water-laid materials dark brownish basalts are found.

The rocks comprised in this part of the section, below the Tranquille beds, evidently represent those holding a similar position in the first part of the section, near the mouth of the Nicola, but differ somewhat from them in lithological character. The greenish and gray pale-coloured tuffaceous agglomerates there seen, are not here represented to anything like the same extent, being replaced by more compact porphyrite. Taking the observed attitudes and measurement of the section of this place, the probable exposed thickness of the strata below the Tranquille beds, is again about 5300 feet, while the minimum possible thickness, according to the observations made, is 3700 feet. The thickness of the Tranquille beds and associated tuffaceous materials appears to be something like 800 feet, being considerably greater than in the lower part of the valley. The porphyrites composing the entire lower division of this part of the section are usually hard, and some of them, apart from their association, might easily be mistaken for rocks of parts of the much older Nicola formation. They generally, however, weather to brown colours, in a manner somewhat different from the typical rocks of that formation.

* Appendix I., No. 62. † Appendix I., No. 55. ‡ Appendix I., No. 61.

Rocks seen
near Skuh'-un
Creek.

The sequence and arrangement of the Tertiary volcanic rocks away from the actual valley of the Nicola, on either side, have not been examined into in detail; but in this vicinity, along the route shown on the map following the north branch of Skuh'-un Creek towards the Pimainus Lakes, it was found, that the lower part of the section above described is repeated, with southerly or south-westerly dips, the lowest beds being next to the faulted contact of the Tertiary with the granites. This repetition occurs in a length of about three miles, measured along the route indicated, from the edge of the granites. In immediate contact with the granites, along the line of fault, some earthy, fine-grained, tuffaceous agglomerates of pale greenish colour are found, which do not appear in the anticlinal near the mouth of Skuh'-un Creek, and are lower than any of the beds seen there. These probably represent the first rocks noted at the mouth of the Nicola River, and though in some respects resembling the Tranquille beds, and apparently implying like these, some contemporaneous water action, they belong to a much lower horizon.

Part 4.

Part 4.—This extends from the end of the last, at the mouth of Smith's Creek, for a distance of four miles, in a bearing of S. 24° E. to the mouth of the next small stream from the north-east. As in Part 2, the valley here nearly follows the main line of strike, the general dip being as before in a south-westward direction. This part of the section, as represented, depends entirely on observations made in 1877, on and near the wagon-road. The rock exposures are few and poor toward both ends, but are good and nearly continuous for more than two miles. The Tranquille beds, as found in this part of the valley, consist to a greater degree than before of coarse, gray and brownish, tuffaceous or felspathic sandstones, in which fragments of carbonaceous matter were in several places observed. The very fine-grained gray, well-bedded tuffaceous rocks before so abundant, are, however, also present here, while a nearly white, fine-grained tuff also appears in considerable volume. All these materials form compact rocks. Near Pulpit Rock considerable exposures occur of rough brownish breccia, which is supposed to underlie the tuffaceous sandstones.

Carbonaceous
matter in
tuffs.

Part 5.

Part 5.—This continues the general section for a further distance of about four miles, to a point on the Nicola a little above the mouth of the Spioos River. The line of section here runs about S. 35° E. Only about a mile of this part of the section is actually included within the Kamloops sheet, but as the section met with in the Nicola Valley from the Spioos to the confluence of the Coldwater is not yet very well understood, while it appears to be moderately legible up to the mouth

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of the Spioos, it is considered advisable to carry the description thus far. Just above the mouth of the Spioos, the lower part of the valley is occupied by a projecting mass of old rocks, consisting of green schistose materials, highly charged with pyrites and weathering rusty. These dip N. 15° E. $< 50^{\circ}$. Between the north-west end of this part of the section and these old rocks, the Tertiary rocks form, so far as has been ascertained, a low synclinal flexure, of which the south-east side progressively overlaps the older projecting mass. The old rocks are confined to the lower part of the valley of the Nicola, where they have a breadth of perhaps half a mile. In the hill above, a brown porphyritic agglomerate covers them, so that but for the erosion of the Nicola River, they would not be seen. In the syncline just referred to, the Tranquille beds are believed to be represented by certain white, hard porphyrites, which appear to be in part bedded and tuffaceous. The reference is, however, made not without some doubt, and subject to future investigation. Where seen, these dip S. 35° E. $< 25^{\circ}$. They were not observed on the south-east side of the syncline nearest to the old projecting mass. Some basaltic rocks appear in the centre of the syncline.

Projection of
older rocks.

Tertiary Rocks to the South-west of the Nicola Valley.

The Tertiary rocks of the rough high country situated between the Nicola, the Thompson and the Nicoamen rivers, constituting the Nicoamen Plateau of the map, have been examined in 1888 and 1889 along a few lines only. The southernmost of the routes followed, leaves the Nicola about a mile beyond the south line of the map, and runs eastward to Za-kwaski Mountain and beyond, being throughout a short distance to the south of the present sheet. The next route, starting from the vicinity of Za-kwaski, runs north-eastward to the Nicola, midway between Skuh'un and Smith's creeks. The third, crosses the plateau from the mouth of the Nicoamen River, reaching the Nicola a few miles above the mouth of the Skuh'un. The last is the only one which can be described as following a travelled trail, the others being merely forced routes through country scarcely practicable for pack-animals.

Routes
followed on
Nicoamen
Plateau.

Between the mouth of the Nicola and that of the Nicoamen, the Thompson River is bounded by Tertiary rocks on both sides, till, within about three miles above the Nicoamen its channel becomes nearly coincident with the line between these rocks on the east and the granitic rocks of the southern part of the Scarped Mountains on the west. About a mile and a half above Drynoch station, the railway track is laid

Thompson
Valley.

Big Slide.

across what is known as the Big Slide, a mass of soft *débris*, which is still in a gradual, if intermittent, state of motion towards the Thompson River. The material of the slide consists of yellowish and brownish soft tuffaceous deposits, completely poached together and packed with fragments of basaltic and other volcanic rocks. It has descended to its present position from a high level on the edge of the Nicoamen Plateau, where rocks of the same kind are still seen in place, and are supposed to represent a continuation of the Tranquille beds described on the Nicola. The outcrop of these beds probably crosses the northern part of the Nicoamen Plateau, but has not been definitely traced there. As viewed from high points on the other side of the Thompson, the Big Slide is found to have originated from the edge of a flat meadow-like area with little pools or lakes, which forms part of the edge of the Nicoamen Plateau here. Where crossed by the railway below, it consists of irregular mounds and ridges, with frequent gaping fissures, and is evidently slowly subsiding upon the inclined surface of hard underlying rocks, the evidences of motion being greatest at seasons when the soil is saturated with moisture.

Near Drynoch.

Below Drynoch station, half-way between mile-posts 170 and 171 on the railway, a small intercalation of greenish tuffaceous rocks, which apparently dip north-eastward at high angles, was observed. This dip is, however, probably local, for between Drynoch and the mouth of the Nicoamen the Tertiary rocks appear to be very much disturbed, and it is often difficult to distinguish between those actually in place and broken portions of the formation which seem to have slipped down toward the great valley of the river. Much bright red, highly ferruginous basaltic material is seen, but seldom distinctly *in situ*.

Disturbed edge of Tertiary.

Where the line of the Thompson becomes practically coincident with that separating the volcanic rocks of the Tertiary on the east and the granites on the west, it is apparently accompanied by faulting or crushing of the margin of the Tertiary rocks, though the original condition seems to have been one of overlap of these rocks upon a steep border of the granites. In cutting down along this line, the river has detached a couple of small edges of the Tertiary, as indicated on the map, and one of these lies just opposite the mouth of the Nicoamen.

Nicoamen.

At Nicoamen, about 200 yards to the north of the bridge across that river, it was reported that coal had been found, and an examination was made of the locality indicated. Carbonaceous shales containing some small fragments of coal or lignite occur at this place. These shales are several feet in thickness, and are overlain by yellowish and greenish shales and shaley clays, apparently composed of tuffaceous

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materials, and underlain by gray coarse sandstones containing a good deal of quartz and evidently derived in large part from the disintegration of the adjacent granites. It is reported that a bed of better lignite is visible near Nicoamen at very low stages of the river, but this was not seen.

The water-bedded intercalation here met with, is believed to represent the horizon of the Tranquille beds, and it is probable that these beds might be traced along the hillside, gradually descending southward to this place, from the point previously mentioned at which the Big Slide has originated from them.

The narrow margin of Tertiary rocks already noted as existing on the west side of the Thompson opposite Nicoamen, may here be referred to in passing. This appears to have a length of about a mile, and according to Mr. McEvoy's observations, the northern part consists of a brownish porphyrite, the southern part of gray arkose sandstones derived from the adjacent granite rocks, with some brown breccia, considerably decomposed. The horizon of the rocks last mentioned is probably about the same with that of the sandstones and shales at Nicoamen.

The rocks forming high cliffs at the fall of the Nicoamen, near its mouth, and seen in ascending the very steep hill on the trail to the north of the river, are chiefly vesicular and amygdaloidal basalts, weathering to red colours. These are believed to follow the sedimentary materials last described, in ascending order. Higher up, and further east, in following the trail across the plateau toward the Nicola, much basalt-breccia or agglomerate is seen. All these rocks preserve a marked lithological uniformity, and from the fall to the summit of the plateau, on the trail, are nearly horizontal, in so far as the attitude of such massive beds could be determined. The trail crosses the plateau at an elevation of about 2660 feet above that of the flat at the foot of the fall, while above the transverse valley along which the trail runs, hills of the same composition rise to a further height of about 500 feet. Thus, on the assumption that the sedimentary and carbonaceous beds near the mouth of the Nicoamen represent the Tranquille beds of the Nicola section, we have for the upper preponderantly basaltic member of the Tertiary in this region, a minimum thickness of about 3100 feet.

The basaltic rocks in this part of the plateau are frequently amygdaloidal, the cavities containing numerous well banded but pale-coloured agates, with zeolites and green chloritic material.

On reaching the steep slopes descending toward the Nicola Valley, the basaltic rocks are found to have a very general south-easterly dip, at an average angle of about 10° ; and before getting down to the

Tranquille
beds.

Tertiary edge
west of
Thompson.

Basaltic series
behind Nico-
amen.

Agates.

Descent to
Nicola Valley.

river, on the line of route followed, bluish and purplish porphyrites appear, similar to the rocks of the same kind in the Nicola Valley which have already been described at length. It is probable that some rocks of this kind here overlie the Tranquille beds, but no distinct section including these beds was met with in descending to the Nicola River at this place.

Higher parts
of Nicoamen
Plateau.

The route first referred to at the beginning of this section of the report, and there described as running from a point on the Nicola about a mile beyond the edge of the map eastward to Za-kwaski, follows the highest parts of the plateau, consisting of ridges and uplands which separate the tributaries of Agate Creek and the Nicoamen River on the north from those of Prospect Creek, a tributary of the Spioos, on the south. A considerable part of the route thus followed is at an elevation of about 6000 feet. As already mentioned, it is everywhere to the south of the map-sheet, its greatest distance from this edge being in one place as much as four miles. Za-kwaski Mountain, the position of which is indicated on the map, lies at about a mile and a half to the south of the south line. The rocks observed on this route were entirely volcanic and chiefly basalts of somewhat varied colour and texture, often brecciated. No approach to a connected section was obtained, and it has not therefore been thought worth while to make any microscopical examination of the isolated specimens brought back. Chalcodony and agates, together with crystalline quartz, are rather notably abundant in amygdaloidal cavities in some of the rocks and small specimens of zeolitic minerals, including stilbite and heulandite, were also found.

Za-kwaski
Mountain,

Composition.

Za-kwaski itself is a block-shaped mass which stands on the south-east margin of this part of the Nicoamen Plateau, overlooking on that side a deep valley in which small branches of the Nicoamen and Prospect Creek head together. Beyond this valley are the granitic rocks of the Lytton Mountains. Though elevated about 450 feet only above neighbouring parts of the plateau, Za-kwaski is a prominent landmark and can be seen from many of the high points occupied by us in the south-western part of the Kamloops sheet. Its actual height is 6600 feet. It is easily climbed on the eastern side, and is composed throughout of a homogeneous, fine-grained, gray augite-porphyr, which rings under the hammer.* A nearly horizontal foliation or flow-structure is present, with two systems of nearly vertical jointage planes, causing the rock to break out easily in quadrangular blocks,

*Appendix I., No. 54.

BRITISH COLUMBIA.]

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with which the slopes are strewn. This rock is very different in appearance from the darker and more basic augite-porphyrates previously described. Macroscopically it resembles a trachyte. The thickness of the mass of which Za-kwaski is composed must be 500 feet or more, and it appears at this place to be the lowest representative of the Tertiary volcanic series, resting directly upon the granites, by overlap. Its precise relation to the Tertiary section as displayed along the Nicola is not known, but it may represent the horizon of the trachyte-like eruptions to which much of the material of the Tranquille beds is due, possibly here near a centre of eruption. A distant view of Za-kwaski from the northern part of Lytton Mountains showed its general relations to the granite and to the overlying basaltic members of the Tertiary volcanic series more closely than these could be observed on the ground itself.

The second route, noted at the beginning of this section of the report as running from the vicinity of Za-kwaski north-eastward to the Nicola, will be found indicated on the map. It follows a high ridge to the east of Agate Creek, of which Mi-mēm-oo, with a height of about 6000 feet is the culminating point. This point and the crest of the ridge for two miles or more in length in its vicinity, is composed of gray, generally pale-coloured rocks of trachytic appearance. All are apparently eruptives, and some are more or less amygdaloidal. The actual bare summit of Mi-mēm-oo is composed of a hard but much decomposed porphyrite.* To the northward of this part of the ridge, basaltic rocks are characteristic, till in the immediate vicinity of the Nicola Valley, the Tranquille beds are found, forming the upper part of the section extending eastward from the mouth of Skuh'un Creek, which has already been described in some detail (p. 181 B).

Nicoamen
Plateau near
Agate Creek.

The observations made on this and the foregoing line of traverse, together with what has been seen on Spioos River and its branch Prospect Creek (of which no description is included in the present report) lead to the belief that the Tertiary volcanic rocks of the south-eastern part of the Nicoamen Plateau are somewhat complicated by low undulations, of which the position and trend have not yet been fully ascertained.

Disturbance
of rocks.

Tertiary Outliers in the Lytton Mountains.

Three isolated patches of Tertiary rocks lying to the south-west of the Nicoamen Plateau, may be mentioned here.

*Appendix I., No. 59.

Patches of
conglomerate
and basalt.

At a height of about 4000 feet, on the north slope of Lytton Mountain, a small outlier of Tertiary conglomerate was discovered. This contains pebbles, and more or less perfectly rounded boulders of granites and of Tertiary volcanic rocks. It is probably a part of the deposit of some body of water which existed during the later stages of the Miocene period of volcanic activity. A little further south on the same mountains, a much larger outlier of grayish and reddish basaltic rocks occurs. This is evidently a portion of the former edge of the flows capping the adjacent Nicola Plateau. The dip of these rocks nearly follows the slope of the hill, being, where observed, about N. 50° E. < 15°.

Tertiary beds
with lignite,
near Fraser.

Another and in some respects a very remarkable outlier of rocks of Tertiary age, occurs near the Fraser, on the west side of the Lytton Mountains, just beyond the bordering line of the present map. This was examined by Mr. A. Bowman in 1885, according to whom it occupies a small flat area at a height of about 800 feet above the line of railway, with a greatest width of possibly as much as half a mile. The rocks found by Mr. Bowman are gray shales with some poorly preserved plant impressions, and small quantities of lignite were also seen by him. It is not known to what stage of the Tertiary this little patch of sedimentary rocks is attributable, but its very low elevation—about 1500 feet above sea-level only—is noteworthy, and for this reason anomalous.

Tertiary Rocks to the North-east of the Nicola Valley.

East side
Thompson
River.

On the east side of the Thompson, above the mouth of the Nicola, the north-eastern edge of the Tertiary is found near the 184th mile-post on the line of railway. The rocks here seen, from the dips observed on both sides of the Thompson, are probably the lowest exposed in this vicinity, but it is believed that their actual junction with the older series to the north is accompanied by faulting, in continuation of the persistent line of fault already noted (p. 177 B). The rocks are grayish, greenish and pinkish-gray agglomerates, rather soft, with a somewhat earthy fracture, but largely composed of porphyritic debris. Nearly on the presumed line of strike of these rocks, on the west side of the river, some beds of tuffaceous sandstone are found, but these were not recognized in a corresponding position on the east side.

Tuffaceous
beds.

Two miles further south, near the 182nd mile-post, about half a mile below the mouth of Pimainous Creek, on this (east) side of the river, a thickness of several hundred feet of well bedded tuffaceous materials is found. These dip about S. 60° W. < 20°, but the dip becomes less to

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the south-westward. The same beds were observed on their line of strike on the opposite side of the Thompson, with similar dips. Lithologically they resemble the Tranquille beds of the Nicola Valley, but it is quite possible that they may represent a lower horizon. Their connection with the rocks of the Nicola Valley section has not been traced out and for the present must remain in doubt.

The line of faulting, which in general bounds the Tertiary volcanic rocks to the north-east of the Nicola, is believed to cross Pimainu Creek about a mile and a half above its mouth. Thence, for about five miles south-eastward in the Pimainus Valley, a selvage of the Tertiary volcanic beds, to the north-east of the fault, appears to lie directly upon the granites. For part of this distance along the valley, its south-west side consists of high cliffs and scarped hills, in which at least 1000 feet of beds is shown. These appear to lie nearly horizontal, and consist of a series of massive beds or layers of somewhat varied appearance, comprising agglomerates and augite-porphyrates of different kinds.* In the higher part of the hills vesicular basalts seem to preponderate, but no bedded tuffaceous materials were here met with, nor were any fragments of this kind or of ordinary sandstones found in the wash of the stream itself.

Fault and exposure in Pimainus Valley.

The Tertiary rocks seen to the north of Skuh'un Creek and near to the edge of the granite in that vicinity, have already been described in connection with the Nicola section. In that part of the main valley of Skuh'un Creek to the west of the granite area, porphyrites of different kinds were seen in several places, but no connected section was obtained. Near the granite edge, the abundance of loose fragments of greenish tuffaceous sandstones gives reason to believe that a rock of this kind outcrops, but it was not actually seen in place.

Skuh'un Valley.

Further to the south-eastward, the valley of Smith's Creek was ascended for the purpose of defining the position of the junction of the Tertiary rocks with the granites. The whole valley and its slopes are so deeply covered with drift materials that little was seen. There is a point on the stream, however, where the debris changes suddenly from an entirely granitic composition and begins to contain a larger proportion of Tertiary rocks, and near this point an exposure was found on the left bank, of hard, yellowish tuffaceous beds, apparently nearly on edge. These are believed to represent the lowest member of the Tertiary at this place and to be in immediate proximity to the line of fault.

Smith's Creek.

Tuffaceous beds.

The next small stream entering the Nicola from the north-east, was also examined for a couple of miles, but without actually reaching the

* Appendix I., No. 56.

edge of the granite. White trachyte-like rocks, are here rather notably abundant,* but on microscopic examination they were found to be mica-porphyrates in composition.

Tertiary Rocks to the North of the Eastern Part of the Nicola.

Projecting
points of
Tertiary.

To the east of the point at which the Nicola enters the Kamloops sheet, the south line of the map cuts the physical and geographical features of the country in a somewhat unfortunate manner. From the lower end of Nicola Lake to the point above mentioned, the Nicola flows for a distance of over seventeen miles to the south of the map, but never at a greater distance than four miles from it. In this part of the valley coal-bearing Tertiary rocks are developed, but only two projecting points of the Tertiary actually extend within the limits of the map. One of these occupies the lower part of the wide tributary valley of Guichon Creek, the other runs up upon the plateau to the west of Clapperton Creek.

Nicola-Cold-
water Coal-
field.

Although thus beyond the limit of the present map, a few words may be inserted here on the coal-bearing strata found about the confluence of the Coldwater and Nicola Rivers. A description of these occurrences is given in my report for 1877-78 (pp. 122 B-126 B) but since that time borings made in the vicinity show that the coal-seams have an extent of at least several miles beneath the alluvial lands of the wide Nicola Valley, a matter which could only be one of inference in 1877. Subsequent investigations have likewise shown that the coal-bearing strata (constituting the Coldwater group of the present report) must be regarded as unconformable below the volcanic Tertiary strata, while they also indicate that the conjecture hazarded in the previous report as to their passage beneath Iron Mountain, is probably incorrect, inasmuch as it now appears to be probable that the mass of this mountain is composed of rocks of the Nicola formation.

Section in
Coal Gully.

The best natural general section of the rocks is that found in Coal Gully, facing the Nicola Valley and about a mile and a half from the bank of the Coldwater. As given in the Report for 1877-78, it is as follows:—

	Feet. In.	
(1.) Soft yellowish sandstone, in thin beds, at the top of the hill.....	32	0
(2.) Coal, laminated, rather soft,	15	4
(3.) Sandstone, rather soft, with some shale.....	89	0
(4.) Coal.....	5	4

* Appendix I, No. 46.

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Feet. In.

(5.) Sandstones with a considerable thickness of shaly beds at the base	141	0
(6.) Coal.....(about)	3	0
(7.) Sandstones, generally in thin beds.....	136	0
(8.) Coal.....(about)	2	5
(9.) Sandstones.....	..	..
	424	1

The two upper beds designated as coals, might be more correctly described as lignite-coals, and it is not certain that any of the coal-beds in this section corresponds with that which has been wrought from time to time in a small exposure on the bank of the Coldwater, which shows a thickness of at least 5 feet 3 inches of workable coal, of good quality and yielding a coherent coke. This is referred to as the "main seam" in the Report of 1877-78, which should be consulted.

Since the above was written, the results of two test borings made in the Nicola Valley in this vicinity by the Nicola Valley Company, in 1891 and 1893, have become available for publication. It would be inappropriate here to enter into details respecting the field, as it lies beyond the edge of the present map-sheet and requires further investigation, but it may be stated that a coal-seam undoubtedly representing the so-called "main seam" has been found in both borings. These borings were put down in accordance with my recommendation, in the flat part of the valley, which is entirely covered by alluvial deposits. The first (No. 5) was situated on Lot 123, Township 91; the second (No. 7) on the east side of the north-west quarter of section 14, both being in the angle between the Nicola and Coldwater rivers. The level of the surface at both places may be considered identical.

Result of recent borings.

In No. 5, the part of the section supposed to represent the main seam is as follows:—

Feet. In.

Coal.....	3	8
Sandstone.....	0	0
Coal.....	1	4
Sandstone.....	0	8
Coal.....	0	7
Total coal.....	5	7

Depth of base of seam from surface, 196 feet 9 inches.

In No. 7, the corresponding portion of the section is as follows:—

	Feet.	In.
Coal.....	0	8
Shale.....	1	1
Coal.....	0	6
Slate.....	0	4
Coal.....	4	4
Total coal.....	5	6

Depth of base of seam from surface, 144 feet 5 inches.

No. 5 was carried down to a depth of 600 feet, and No. 7 to 563 feet, cutting, in each case, through several more thin seams not of workable dimensions.

The coal.

The coals obtained in these borings yield a good strong coke. The two borings are distant from each other about a mile and a half, and although the natural outcrops to the south of the line joining the borings show some stratigraphical complication, the result of these tests is to indicate that a considerable undisturbed and easily workable coal-field exists beneath the valley.

From the above short note on the Nicola-Coldwater coal-field proper, we may return to the northern arms of rocks of the same age which, as already stated, actually appear upon the map.

Rocks from end of section to Guichon Creek.

A mile and three-quarters eastward along the road from the projecting boss of old rocks which terminates the diagrammatic section along the Nicola, another similar projection of old rocks appears in the bottom of the valley, with a width on the road of about eight-tenths of a mile. The level of the river throughout this part of its length, is evidently not far from the local base of the Tertiary, but no underlying sedimentary deposits were actually seen here. At about two miles further eastward, within a mile of the bridge across Guichon Creek, a hill of whitish trachytic-like rock borders the road. This rock has a dull fracture, is in part an agglomerate and appears to be rudely bedded. It is believed to overlies directly the sedimentary deposits of the lower part of the Guichon Valley, next to be referred to.

Coldwater beds on Guichon Creek.

These sedimentary rocks have been noticed in my report of 1877 (p. 126 B), in connection with the coal-bearing beds seen near the mouth of the Coldwater. A further attempt has since been made to acquire more precise data respecting them, but with indifferent success, the whole of the low country which they occupy being more or less deeply drift-covered. The area actually held here by the Tertiary sedimentary rocks is, I believe, now defined with some approach to accuracy,

though, as represented on the map, the outlines are largely dependent on the contour of the surface, taken in connection with observed outcrops of the older rocks which in some places fix maximum limits.

The Tertiary rocks themselves, here consist of soft yellowish and pale gray shales and shaly sandstones, with some beds of rather earthy, whitish, arkose sandstone of medium grain, containing much sub-angular quartz, mingled with decomposed felspar, and evidently resulting chiefly from the disintegration of granite. These are seen, apparently in place, in some of the gullies on the east side of the valley, between the wagon-road and the base of the steeper hill, but there is so much evidence of old (probably pre-glacial) land slides, and the whole surface of these soft deposits has been so completely poached up during the glacial period, that it is very seldom possible to be sure that any of the beds are undisturbed. They are frequently incorporated in considerable quantity in the boulder-clay, which in consequence assumes yellowish tints locally.

Character of the strata.

The broken shaly materials are found in several places, particularly in bluffs along the immediate valley of the stream, to hold fragments of lignite and of ironstone. The lignite was not anywhere seen in place, and although beds of lignite or coal have been reported here, it is probable that the reports depend merely on the occurrence of such fragments.

Lignite and ironstone.

It is in the main, sufficiently clear, that the lower part of the Guichon Creek valley is floored with these Tertiary sedimentary deposits, which have been laid down when it formed an arm or inlet of the body of water in connection with which the coal-bearing strata of the vicinity of the mouth of the Coldwater were deposited. It is probable that the beds here seen at the surface, represent those of the higher part of the section near the mouth of the Coldwater, which they closely resemble lithologically, as well as in the association with them of lignite, instead of the coal found near the base of the formation at the Coldwater. It is further probable, that these higher beds here transgressively overlap the old rocks, for if their occurrence were due to a subsequent synclinal flexure, the upturned edges of the harder and more massive sandstones and conglomerates of the lower part of the formation, would almost inevitably have formed bold outcrops about the edges of the basin. Thus, if these lower beds are here present, it may be presumed that they occupy the deeper part of the original valley without coming to the surface. This would indicate that if a search is to be made here for the better fuels of the lower beds, it must be conducted by boring somewhere near the middle line

Probable relations of the beds

Site recommended for boring.

of the valley, in the vicinity of the present stream. It appears to be desirable that such a test should be made, and the circumstances seem to show that the most favourable place would be about two miles above the bridge over Guichon Creek, near the point of intersection of the creek with the south line of the present map-sheet.

Coldwater
beds near
Clapperton
Creek.

The information gained respecting the second of these northerly projections of the Tertiary rocks, that to the west of Clapperton Creek, depends in large part on the examination of the Nicola Valley to the south of the area of the map. Its form, as shown upon the map, is probably nearly correct, but the depth of cover upon this part of the plateau renders it to some extent uncertain. It may extend somewhat further to the north, and its western edge may also lie somewhat further to the westward than represented. It is also quite probable that additional, but undiscovered, small outliers of these rocks occur on the plateau beyond its main area.

Sandstone
outcrops.

Just beyond the border of the map, a mile and a half west of Mr. Clapperton's house, in the flat land of the valley, exposures of gray, siliceous sandstones like those associated with the coal at the mouth of the Coldwater are seen. These contain some pebbly bands, and dip westward at angles of about 20° , toward the base of the neighbouring hills. The thickness exposed is fully 100 feet. About 100 yards further west, on approaching the base of the steep hills, and on their slopes for some hundreds of feet up, Tertiary rocks are again seen, with prevalent easterly dips, at high angles, ranging apparently from about 40° to nearly vertical. The typical gray siliceous sandstones are not represented here, nor have they been recognized in any part of this area actually included in the map, which is occupied by rocks like those about to be noticed, which probably hold a lower position than the sandstones and represent the basal beds of the Tertiary at this place.

Conglom-
erates.

These rocks are in the main conglomerates, but are accompanied by finer grained materials, and from their somewhat peculiar character and their relations to the lowest members of the Tertiary elsewhere, require a few words of description. The upper beds are gray conglomerates, composed of well rounded pebbles thickly packed together. The pebbles are generally small, seldom more than a few inches in diameter. Compact cherty pebbles of pale tints predominate, but there is also a considerable proportion of hard black argillite. In the lower beds, the character of the conglomerates is considerably changed. The material is much less perfectly rounded, in many places resembling a breccia, and although it is somewhat varied in composition, much of

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it is evidently of local origin and derived from the immediately underlying or adjacent beds of the Nicola formation, comprising gray, purplish, blackish and greenish porphyrite or diabase rocks. Fragments of granite rocks are also abundant and cherty material like that found in the overlying conglomerates is not entirely wanting.

Rough basal
Conglomerates.

Fragments contained in these lower conglomerates were in some places observed to be as much as a foot or two feet in diameter. The fine-grained beds associated with them are essentially composed of similar material, which forms arkose or grauwacke sandstones. These are normally dark in colour and hard, but in many places they have been more or less decomposed and dolomitized, probably as a result of the action of heated waters from below, in a manner identical with that observed to have occurred in the case of the lowest Tertiary beds in some other parts of the region (see pp. 163 B, 125 B, 235 B).

Dolomitized
sandstones.

As a result of the peculiar composition, excessive induration and local alteration of these basal beds, their relation to the Tertiary coal-bearing rocks of the vicinity is not at first apparent, and their line of contact with the unconformably underlying rocks can only be traced out in detail with difficulty. The rock immediately underlying these basal Tertiary beds, where seen near the wagon-road, about four miles south-west of Mr. Clapperton's house, is a dark purplish-black porphyrite, speckled with small light marks representing decomposed felspar. This forms an abundant constituent of the basal conglomerate of the vicinity. Further north, on the summit of the plateau, where crossed by our line of route as shown on the map, the basal conglomerates are underlain by a rather coarsely porphyritic purplish rock. This is an augite-porphyrine with an abundance of felspar crystals and holding a little quartz. It is easily recognized as forming a great part of the material of the conglomerates in its vicinity, and often occurs in large fragments in them. On the east side of the Tertiary area, where it runs up on the plateau, hard brecciated, greenish, feldspathic rocks appear to bound it. It is probable that the junction is here a faulted one, the line of fault running nearly north-and-south. When last seen to the north-west, on the plateau, the basal beds, here comprising a good deal of rather soft brownish arkose sandstone, dip north-eastward at low angles. Elsewhere, the dips are almost invariably high, a circumstance apparently due to local folding nearly parallel to the supposed line of fault.

Area difficult
to define.

Local constituent of conglomerates.

Probable
fault.

Altogether, the stratigraphical relations of the beds in this vicinity is confused and somewhat perplexing, but it is sufficiently clear that we have here the overlap, upon the pre-existing surface, of a portion of the

General
relations.

lowest beds of the Nicola-Coldwater coal-bearing rocks (Coldwater group), representing a part of the shore of the lake in which these beds were laid down. The thickness of the conglomerates and associated beds could not be precisely estimated, but must be at least several hundred feet.

Horizon.

All the beds here particularly described are undoubtedly below the known coal-bearing horizons of the vicinity, and there is very little prospect of the discovery of coal in connection with them. This does not apply, however, to the gray siliceous sandstones seen in the flat land a mile and a half west of Clapperton's, and it is possible that coal seams might be discovered by boring in this part of the valley.

Correspondence with other localities.

The notes above given, will show how closely analogous the basal beds of the Tertiary at this place are to those already described in the neighbourhood of Kamloops Lake (pp. 160 B, 163 B). The basal conglomerates are almost identical in character, with only such differences as result from the local nature of their material in each case. The overlying cherty conglomerates are even more nearly alike, and the problem presented by the occurrence of cherty material in so great quantity is the same in each case. Here, as elsewhere, volcanic materials referable to the Tertiary period are entirely wanting in the conglomerates, as they are also in the sandstones of the Nicola-Coldwater coal basin throughout its extent.

Places Suitable for Boring in Search of Coal.

Position of Coldwater beds.

From a practical point of view, the main result to be derived from the working out of the stratigraphical order and details of the flexures of the Tertiary beds of the Nicola Valley, is a knowledge of the localities in that valley in which coal-seams may reasonably be looked for. What has been said in previous pages, and more particularly in the account given of the composition of the Tertiary as a whole, will have rendered it evident that the Coldwater beds, with which the coal is associated in this district, represent portions of a sedimentary formation filling hollows, either those occurring in the preexisting surface, or those produced by the folding or faulting down of the formation.

Possible existence of coal on Lower Nicola.

Some account of the Nicola-Coldwater coal basin and of its extension in the lower part of the Guichon Valley has already been given. Further to the north-westward, the coal-bearing beds are nowhere seen along the Nicola Valley. Where, in a couple of places, the underlying rocks come to the surface, the strata of the volcanic Tertiary, overlap them without the intervention of the Coldwater beds, and these, if

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present, occupy the lower parts of hollows of the old surface which have not been exposed by the later folding and denudation.

Thus, to the westward of Guichon Creek (where the site for an experimental boring has already been indicated (p. 193 B), it is only possible to note a few places in which the lowest volcanic beds of the Tertiary come near to the surface, and where, by means of boring, it can be ascertained, at least cost, whether the coal-bearing Coldwater beds underlie them or not. Further, were the Coldwater beds actually found to occur in any of these places, it does not by any means necessarily follow that they would continue to be coal-bearing; for the coal-seams are the result of the accumulation of large quantities of vegetable material, and the swampy areas in which such accumulation took place must have been bordered on all sides by higher and drier lands of which the vegetation decayed as it was produced, and without leaving any trace.

The following places may, however, be mentioned as those in which it is desirable that experiments by boring should be made, and where, if coal should be found to exist, it may be more easily utilized, because nearer to the main line of railway communication through the country. Places suggested for experimental boring.

1. Nicola Valley from three-quarters of a mile to a mile east of the road-crossing of Skuh'un Creek.

2. Nicola Valley, near the bridge at its mouth, or within half a mile above the bridge. At both these places it is believed that a boring would begin, at the surface, at a horizon low down in the volcanic accumulations of the Tertiary, and would within a few hundred feet reach the base of these rocks. Whenever the older underlying rocks may be reached, in either place, the boring should stop, but some care would require to be exercised in the recognition of these rocks, as they do not always differ very markedly from some of the Tertiary volcanic materials.

3. Mouth of the Nicoamen River, above the railway bridge and near the waterfall. It is not quite certain whether the beds containing some lignite or coal near Nicoamen are referable to the Tranquille horizon or to that of the Coldwater, but in either case the discovery of workable coal or lignite at this point would be of importance. The general section of the Tertiary rocks already given, will afford the means of deciding the horizon as any boring which may be made here progresses. It would be advisable to begin the boring as far up the stream as may be possible without materially increasing the elevation, in order to avoid the zone of crushing and disturbance which here characterizes the junction of the Tertiary rocks with the granitic

Possible auriferous gravels. rocks. The possible occurrence of a buried pre-Miocene river-channel near this place, indicates the advisability of paying special attention to any beds of gravel or conglomerate which may be met with in boring, as these might be found to be auriferous.

Some other localities might be indicated as of subsidiary importance in connection with the search for coal, but those mentioned are, in so far as the structure of the region is understood, undoubtedly the first, (to the westward of Guichon Creek,) at which systematic boring operations might be made, and the results obtained should themselves go far to indicate both the advisability of further explorations and the places in which these should be conducted.

Tertiary Rocks of the Clear Mountains, Mount Murray, Arthur's Seat, Etc.

Tertiary volcanic range. The mountains above designated, form a nearly continuous range, which may be regarded as running from the vicinity of Spence's Bridge on the Thompson for about twenty-six miles in a north-westward bearing. Chi-poo-in Mountain and Mount Martley, the two most northern summits of the Clear Mountains, are not included here, as they are composed of granites and other rocks much older than those of the Tertiary.

Height of summits. The range of Tertiary mountains thus defined, is a most important feature of the orography of the area included in the map-sheet. The Nicoamen Plateau may, in a general way, be said to form its further continuation to the south-eastward, but the heights at which the volcanic rocks occur in the range here particularly referred to, are greater even than those of the culminating parts of the Nicoamen Plateau—greater indeed than that of any other occurrence of similar rocks in the entire region. The elevations of the principal points in this range are as follow:—Arthur's Seat, 5500 feet; Mount Murray, 6880 feet; Blustry Mountain, 6740; Cairn Mountain, 7650 feet.

A line of volcanic eruption. Although it has now been determined that the rocks composing these mountains are referable to the volcanic series of the Tertiary, and that they represent the basal portions of great accumulations of that kind formed along the main line of eruption, chiefly during its earlier stages, this result has not been arrived at without prolonged and careful investigation of all their relations in the field.

Earlier views respecting these rocks. The area occupied by these rocks, being rugged and difficult of access, was necessarily left unexplored during the reconnaissance work of 1877, which was confined to a few months of a single summer. The

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only place in which these rocks were then actually examined, was along the east side of the Fraser above Fountain Creek, and they were at that time, though with doubt, connected with the Cretaceous strata of the vicinity.* This was done because of their contiguity to the Cretaceous rocks and their lithological resemblance to certain "porphyrites" which had been found to contain Earlier Cretaceous fossils in the more northern parts of British Columbia in 1875 and 1876. At the other extremity of the area here under description, Arthur's Seat and adjacent mountains, seen only from a distance, were erroneously supposed to represent a continuation of the crystalline rocks of the southern portion of the Scarp Mountains. As the work upon which the present report is based progressed, it became gradually apparent that these rocks were not attached to the Cretaceous, and that although showing some points of resemblance to the volcanic materials of Triassic and Carboniferous age so extensively developed in the region, they were distinct also from these. Eventually, their intimate association with distinctly Tertiary volcanic products was established, and their connection with the older Tertiary volcanic rocks of the porphyrite class, as displayed along the Nicola River, became clear.

Miocene age
determined.

Without entering into details respecting the character and mode of occurrence of the rocks at each locality where they have been examined, it will now be attempted to give a short general sketch of them.

Arthur's Seat, so named by Mr. John Murray who has long resided near its base, at Spence's Bridge, is a remarkably picturesque mountain as viewed from the Thompson Valley, to which it presents a bold front crowned by lofty mural cliffs. The rocks of this mountain were to some extent taken as typical of those of the whole range which is continued north-westward by Mount Murray and the Clear Mountains. Its crest was not actually reached by us, though this might easily be accomplished from the westward if desired, but very large blocks which had fallen from all parts of its face were examined on the side of the Thompson, its southern flank was crossed at a high elevation, and the rocks of its northern side were examined and collected along the line of Murray Creek. Of the rocks obtained at these localities, a number have been subjected to microscopical examination by Mr. Ferrier, and the greater part of these have been found to be augite-porphyrates, with some diabase-porphyrates and gabbro.† In colour they range from grayish-green to bluish-gray, and

Arthur's Seat.

Characteristic
rocks.

* Report of Progress, Geol. Surv. Can., 1877-78, p. 111 B.

† Appendix I., Nos. 47, 49, 51, 52.

in texture from fine-grained rocks of which the porphyritic structure is scarcely visible macroscopically, to others with a fine-grained base in which felspar crystals are clearly discernible, and again to crystalline rocks of a distinctly speckled or spotted appearance throughout. Some of these rocks are evidently fragmental in structure, but most of them appear to represent old flows of molten matter.

Murray Creek.

At the waterfall near the mouth of Murray Creek, the rocks are very much shattered and conspicuously reddened. They consist of porphyrites and of a trachyte-like material, one being in all probability intrusive in the other, but the broken character of the exposures renders it difficult to determine which of them is the older at this place.

Skoon-ko' Valley.

On the upper part of Skoon-ko' Creek, to the west of Arthur's Seat, the rocks displayed are somewhat more varied in character and are distinctly arranged in somewhat massive beds, which dip at rather low angles, but of which the direction and amount of dip is irregular and difficult to follow. The order is in general, however, an ascending one, from lower to higher levels on the hills. The hill side to the north of the valley was ascended by Mr. McEvoy at two places indicated on the map. At the first of these, the general dip appeared to be southerly at angles of 10° to 30° . The lowest rock seen is a bluish-gray, much decomposed, amygdaloidal augite-porphyrite.* This is overlain by a fine-grained, greenish-gray agglomerate, followed by a distinctly bedded pale, tuffaceous rock. At the second locality, some ordinary sedimentary sandstones occupy the bottom of the valley. These underlie the volcanic rocks and will be referred to again in the sequel. Above them is a fine-grained, yellow amygdaloid, then a pale gray trachyte-like material, then some brown and greenish rocks which were classed in the field as "basalts," but of which no specimens were brought back. Overlying these are beds of rather fine-grained agglomerate, composed chiefly of porphyritic fragments of gray, brown and purplish colours. Some of these fragments are evidently derived from massive rocks in the lower part of the series, seen along the valley of the stream between the two localities above specially noticed.

Scarped Mountains.

The northern part of the Scarped Mountains, to the south of Arthur's Seat, appears to consist of rocks very similar in character to those of that mountain, in so far as they have been examined. Along the west side of the Thompson south of Skoon-ko' Creek, bluish and greenish-gray porphyrites of varied texture, generally massive, but sometimes agglomeritic, are characteristic. On the west side of these

* Appendix I., No. 50.

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mountains, the general dip of the volcanic rocks in the mass, was very clearly seen from Botanie Mountain, whence their outcrops can be traced along the hill-side to the east of Botanie Creek. The dip is about east-north-east at angles of from 15° to 30°. The rocks themselves were not here closely examined, but specimens representing the lower members, near to the bottom of the valley, were obtained in three places, as follows:—Half a mile below Botanie Lake, a fine-grained, purple-gray felspathic rock with flow-structure. Two miles below Botanie Lake, a fine-grained, dark augite-porphyrity (?) with green-faced divisional planes. Four miles and a half below Botanie Lake, a gray porphyryite.

Botanie
Valley.

The southern line of the volcanic rocks, crossing the Scarped Mountains, as shown on the map, depends chiefly upon distant views of these mountains from Botanie and Lytton mountains. It was not actually traced across this rugged range, and may therefore be held subject to modification in detail. The summit, marked "5860 feet," in particular, was referred with doubt, from its appearance, to the granitic series.

The Tertiary volcanic rocks appear to have been stripped from the southern part of the Scarped Mountains by denudation, but the underlying granitic and gneissic materials bear evidence of the proximity of the great line of volcanic eruption in their extremely shattered and disturbed character. They are traversed by numerous dykes of trappean material, fractured throughout in every direction and much altered by heat or solfataric action.

State of under-
lying
granites.

Mount Murray, at the head of Murray Creek, was occupied as a point of observation and a triangulation station. It is composed of rocks evidently the same as those seen along the valley of the creek and in Arthur's Seat. They are generally gray or greenish-gray porphyrites, usually massive, but often distinctly fragmental, and constituting agglomerates. Along the crest of the mountain, near the summit, some red fine-grained beds with small porphyritic crystals occur, which are nearly horizontal; but generally it is not possible to determine the lie of the beds. The actual summit is composed of a gray augite-porphyrity.*

Mount
Murray.

From Mount Murray, an excellent view of the whole surrounding region and particularly of the southern parts of the Clear Mountains proper, was gained.

* Appendix I., No. 52.

Botanie Val-
ley. Sand-
stones.

The western edge of the volcanic rocks, approximately follows the line of the valley in which Botanie and Pasulko lakes are situated, and between these lakes are some interesting outcrops of ordinary sedimentary materials which underlie the great volcanic mass. These appear to consist of sandstones and argillites not distinctly containing volcanic materials, but holding occasional carbonaceous fragments and obscure plant impressions. Conglomerates also occur, and these were particularly observed on the north branch of La-loo-wissin Creek, where they pass into ordinary sandstones of pale yellowish colours. The approximate outcrop of these sedimentary beds is indicated on the map, and though their precise age remains uncertain, it is probable that they may be regarded as forming an extension of the sedimentary beds met with in Hat Creek and described on another page (p. 207 B).

Plateau near
Lookout
Point.

To the north-eastward of Murray Creek and Mount Murray, the Tertiary volcanic rocks continue over a tract of country about five miles in breadth, extending from the Thompson River to the headwaters of Hat Creek, with a length of some fifteen miles. This tract is high and rough, but with some tendency to a plateau-like character as seen from Mount Murray. Lookout Point, rising from it, reaches an elevation of 6600 feet.

Character of
line between
basalts and
porphyrites.

The greater part of this area is believed to be characterized by rocks referable to the earlier stages of the volcanic eruptions, and like those described in the foregoing pages of this section of the report. Its north-western part is, however, evidently covered by basaltic rocks in nearly horizontal flows. The attempt made on the map to outline these two classes of rocks in this region and in that of the Clear Mountains, must be accepted rather as an indication of their existence than as an actual definition of their areas, for no sufficiently detailed examination of their boundary has been made. The exploration of the tract of high country here particularly referred to, was in fact confined to the vicinity of Murray Creek, the Thompson River, Twaal Creek and Blue-earth Creek. The rocks met with on the line of Murray Creek have already been noticed, but a few words may be added respecting those seen on the other routes mentioned.

West side
Thompson
Valley.

On the west side of the Thompson, the north-eastern edge of the Tertiary is nearly opposite In-kai-kuh' Creek, where its beds are found in contact with black slaty argillites and quartzites of the C  che Creek formation. Porphyritic dykes, evidently due to the period of Tertiary eruption, traverse the older rocks near the line of junction, and the Tertiary volcanic rocks near their margin are found to be much disturbed. The junction is probably here a faulted one, the fault being

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the same with that which runs so persistently to the north-east of the Nicola Valley.

Near the edge of the Tertiary, a well bedded intercalation of green-gray tuffaceous sandstone appears, dipping S. 35° W. < 60°. The exceptionally high dip is explained by the proximity of the fault. This stratified intercalation was not recognized on the opposite or east side of the Thompson, but about a mile further south (half a mile above Twaal Creek), another outcrop of similar tuffaceous sandstone occurs on the west side of the river. This dips S. 65° W. < 30°. It was estimated to be about one hundred feet in thickness, and is evidently the same with that noted on the east side of the river, opposite (p. 188 B).

Tuffaceous sandstones.

Below the mouth of Twaal Creek, considerable exposures are found of a peculiar gray concretionary rock not elsewhere seen in the Tertiary. This is described by Mr. Ferrier as a quartzless porphyry (orthophyre) with well marked spherulitic structure.* The other rocks seen along this part of the Thompson are greenish and gray porphyrites of the usual character, occasionally fragmental.

Orthophyre.

Similar rocks occur along the Twaal Valley, with the addition of some reddish-gray porphyrite, and in one place of a gray dacite which contains numerous large grains of quartz with rounded outlines.†

The bedded tuffaceous layers seen on the Thompson were not found in this valley, but the hillsides along it are rather heavily drift-covered, and the exposures in consequence imperfect. At the head of the valley the volcanic rocks are in contact with the limestones of the Cache Creek formation, but it was not ascertained whether the line of junction continues to be a faulted one here.

Blue-earth Creek heads in the same valley as that in which Twaal Creek rises, but flows in the opposite direction, to Hat Creek. This part of the valley nearly coincides with the edge of the Tertiary volcanic rocks, which occupy the country to the south, while the north side of the valley is characterized by limestone, often in the form of bold cliffs. The step-like outlines of the high plateau rising toward Lookout Point, to the southward, indicate that it is chiefly composed of basalts or similar rocks in nearly horizontal flows, and different varieties of such rocks are found on the slopes toward Blue-earth Creek. At one place, just below the little lake in which the creek rises, the Tertiary rocks seen actually resting on the limestones, consist of yellowish and greenish-blue soft tuffaceous deposits, contain-

Blue-earth Creek.

Local base of volcanic rocks.

* Appendix I., No. 43.

† Appendix I., No. 49.

ing fragments of basalts and hard concretionary masses of the same blue colour. This material appears to have been deposited against an originally steeply sloping surface of the limestone; but there is nothing to show that it is at all near the true base of the Tertiary formation.

Southern part
of Clear
Mountains.

The valley which runs from the head of the north branch of La-loo-wissin Creek to the head of Hat Creek, may be regarded as separating the Clear Mountains proper from Mount Murray and others previously described. As seen from the summit of Mount Murray, the high broken region forming the southern part of the Clear Mountains shows the well marked outcrops of massive volcanic beds dipping at low angles to the northward. The same observation was repeated in views had of the western side of this part of the range from As-kom Mountain, on the opposite side of the Fraser, and from a ridge on the east side of the Fraser, in its valley and near the mouth of Cinquefoil Creek. From the two last mentioned places, however, the relation of these rocks to those of the granite series was also very clearly made out, the scarped hill sides sloping toward the Fraser Valley being composed in their lower parts of granite and diorites, upon which, further back and at a greater height above the river, the volcanic materials rest often nearly horizontally. As seen from the Fraser Valley, the overlying volcanic rocks often appear to form rugged and bold hills, but when viewed from a greater elevation, these are found to be merely the scarped ends of ridges and spurs fringing the broken edges of the central part of the range.



FIG. 5.—DIAGRAMMATIC SECTION NEAR THE MOUTH OF CINQUEFOIL CREEK.

a. Granitic and dioritic rocks. b. Cretaceous. c. Volcanic rocks of the Tertiary.

Shattered
underlying
granites.

Along the Fraser Valley, from the vicinity of La-loo-wissin Creek to that of Cinquefoil Creek, the underlying diorites and granites are extremely shattered, and weather down easily into rubbly slopes of angular débris. These rocks are in fact affected in a manner precisely similar to those of the southern part of the Scarped Mountains (p. 201b), and like them represent a portion of the old floor upon which the volcanic accumulations occurred, near to the central line of eruption.

Summits
of the Clear
Mountains.

The summit of the Clear Mountains was reached, by following up the valley of a small stream which empties into Hat Creek opposite Blue-earth Creek. So far as examined, the eastern flanks of the range, all

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CINQUEFOIL CREEK.

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along the upper part of Hat Creek, are largely composed of basaltic rocks, while similar rocks occur high up on the north-eastern flanks of Cairn Mountain, and also in several (or many) other places along the range. On the map, it has been possible to indicate these occurrences only in a general way, or in certain special localities in which they have been observed. Here, as elsewhere, the distinction made between the older and newer volcanic rocks must be considered as approximate merely, and as being much inferior in accuracy to the outlines of the Tertiary rocks as a whole. The rocks observed on the higher parts of the Clear Mountain range, may be described as consisting in the main of gray, blackish, purplish and greenish-gray porphyrites, probably for the most part augite-porphyrates. They are often massive, and represent eruptive materials, but agglomerates of similar composition are also common. The occurrence of basaltic rocks on the eastern flanks of the range has just been alluded to. On the western slopes of Cairn Mountain, two or three distinct outliers of similar rocks were observed, which still preserve their slope, away from the axis of the range and toward the Three-lake Valley. Certain purplish porphyrites which are somewhat less compact in texture than usual, appear to immediately underlie the basalts, while the dense and hard, gray and greenish porphyrites, occupy lower positions in the series and are prominent about the crests of the range.

Basaltic out-
liers.

A notable feature in the higher parts of these mountains and toward their axis, is the abundance of yellowish and whitish crumbling rocks, which give rise to slides of broken material of the same colours, very conspicuous from a distance. These, on investigation, proved to be merely portions of the ordinary porphyrites which had become highly charged with iron pyrites, and which, in part from the decomposition of the pyrites and the action of the liberated acids on the containing rocks, in part apparently from solfataric action which may have occurred during the deposition of the pyrites, have become decomposed and bleached. Decomposed rocks of this character were found to be particularly abundant in the vicinity of Cairn and Blustry mountains. Specimens of them were collected and subjected to analysis, in order to ascertain whether they might contain any gold, but they proved to be barren. The pyritization and decomposition of the rocks here referred to, may be supposed to have occurred during the period of decadence of the volcanic forces to which the formation of the Clear Mountains as a whole is due.

Masses of de-
composed
rocks.

Some miles to the north of Cairn Mountain, the Clear Mountains were crossed by ascending the valley of Limestone Creek and descend-
ing from its sources to the Three-lake Valley. Limestone Creek and the

Rocks tested
for gold.

Limestone
Creek.

gap through which the summit is crossed, coincide as nearly as possible with the northern edge of the Tertiary volcanic rocks of this place, the mountains to the north being composed of limestones and associated Paleozoic rocks, with granite. Beyond the summit, on the west side, the route followed leaves the valley of Eleven-mile Creek at its head and descends along spurs composed of the volcanic rocks toward the Three-lake Valley. On this route, the volcanic rocks met with are chiefly grayish and purplish porphyrites of the usual kind, but near the summit, a small area of basalt was observed.

Three-lake
Valley.

To the west of the Clear Mountain range, the Three-lake Valley has been excavated along the line of junction of the Tertiary volcanic rocks, with those of the Cretaceous series which constitute Fountain Ridge. Some difficulty is occasionally found, in small exposures, in separating the porphyrites of Tertiary age from the largely felspathic sandstones and grauwaacks of the Cretaceous, but the valley as a whole appears to follow the line of contact very closely.

Decomposed
and shattered
rocks near
Fountain.

On the Fraser River, to the north of Three-lake Valley and east of the mouth of Fountain Creek, the junction of the Cretaceous rocks with the volcanic Tertiary rocks of the Clear Mountain mass, is obscured by considerable disturbance and alteration. Both the Cretaceous sandstones and the volcanic rocks have been discoloured and silicified by heated water or vapours, subsequent to the date of their deposition, but as a result of a careful examination on the ground, the boundary has been laid down as it appears on the map. Where unaltered, the volcanic materials are found to be gray and purplish porphyrites of the usual character. These are seen on Eleven-mile Creek, near the wagon-road and elsewhere in the vicinity. The boundary of the Tertiary volcanic rocks on the upper part of Eleven-mile Creek and to the east of the Fraser, for a couple of miles north of that stream, is not so definite, as it was not actually traced out in detail on the ground.

Fountain to
Pavilion
Creek.

The volcanic rocks here, however, form a narrow band along the Fraser Valley, while the northern part of the Clear Mountains consists of Paleozoic and granitoid rocks, and the Camelsfoot Range, to the west of the Fraser, is Cretaceous. About a mile south of Eighteen-mile Creek, some decomposed volcanic rocks remarkable for their brilliant and varied colouring, appear on the east of the road and between it and the Fraser River. At the mouth of Pavilion Creek, the Tertiary volcanic rocks have a width, to the east of the Fraser, of about a quarter of a mile only.

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Less than a mile north of Fourteen-mile Creek and just east of the wagon-road, a small patch of rather soft, coarse conglomerate occurs. Most of the boulders and pebbles consist of porphyrite rocks like those of the Clear Mountains, while some are granites. The height of this little outlier above the Fraser is about 1000 feet, and it appears to represent a remnant of an old bed of the Fraser, which, perhaps owing to some local induration, has escaped denudation. The height above the present river seems to indicate that it may be assigned to one of the early stages of the period of Pliocene erosion. This, with any other similar deposits which may be found, appear to be worth examining as possibly containing gold brought down during the period of ancient river erosion.

Pliocene conglomerate.

Possibly auriferous.

Tertiary Rocks of Hat Creek, Pavilion Mountain and Vicinity.

The upper valley of Hat Creek, which runs from south to north along the east base of the Clear Mountains, is largely floored by sedimentary Tertiary beds—generally soft shales and sandstones. The whole surface of this wide valley is, however, so thickly covered with drift deposits, that it is impossible to define the area of these Tertiary beds with any precision. The outline given upon the map is probably as nearly exact as is possible from observation of the natural exposures, but it is really only in that part of the valley near Limestone and Medicine Creeks, and thence northward, that the Tertiary sedimentary deposits are actually exposed. Thus, the southern extent of these beds, and their width in the southern part of the valley is particularly open to doubt.

The occurrence of an important deposit of lignite-coal on Hat Creek, near the east entrance of Marble Cañon, has long been known. This locality was visited by me in 1877, and some description of it is given in the report for that year, from which the following is quoted:—

“A locality of some interest in connection with the Tertiary is found on Hat Creek, about a mile above its abrupt bend at the eastern entrance to Marble Cañon. The exposures here extend for about 500 yards along the stream, but are not continuous, and the arrangement of the beds is somewhat complicated by the fact that considerable landslips have occurred in some parts of the banks. These have formed hollows beyond the margin of the bank, in two of which pools now lie. A great thickness of lignite coal, however, occurs here, associated with sandy or clayey, yellowish, grayish or purplish beds, which are generally rather incoherent. The stream nearly follows the strike of the beds, so that the same deposit of lignite is seen in a number of

Great bed of lignite.

Description from Report of 1877-78.

places. The lowest good exposures shows over thirteen feet of lignite, neither the top nor the base of the bed being seen. The lignite is pure throughout, with the exception of a few lenticular or more or less irregular masses formed by silicified or calcified stumps. In following up the stream, lignite of the same kind is frequently seen, and continues to show occasional masses of fossil wood of the kinds above described, but is without shale. Some portions of the wood have been changed to ironstone of good quality, which might be of value if the lignite bed were being worked. At the highest good exposure the beds are dipping into the western bank of the brook at an angle of 30° , and are probably undisturbed. The bank was here scarped down, and the section carefully examined. The result may be stated as follows, in descending order:—

		Feet.	In.
Natural section observed.	(1.) Grayish and brownish shales and sandy clays, with lignite in seams a few inches thick, about.	20	0
	(2.) <i>Lignite</i> , with shaly and lenticular layers of siliceous matter, ironstone and shale. <i>Lignite</i> of fair quality forms about two-thirds of the whole, and contains much crumbling amber.....	26	0
	(3.) <i>Lignite</i> , with little or no shale or other impurity. Below very compact, rather softer in the upper layers.....	42	0
		88	0

"The bottom of this enormous lignite bed was not seen, the measurement going only to the water of the brook, beneath which it is concealed."

Work done in 1889. In 1889 some attempt was made, by drifting and uncovering the outcrops, to determine the extent and value of this lignite deposit, but the amount of work done was inconsiderable and the additional information gained by it not great. The openings were visited by me in the same year, when attention was also directed to ascertaining the limits and character of the field as a whole. The paucity of information to be derived from the exploratory work, results chiefly from the fact that the beds are much disturbed where they outcrop along the banks of this part of the stream, and that an even greater amount of disturbance and irregularity has been brought to light by the work done, than could have been previously anticipated. This disturbance may possibly be entirely due to the effect of old (perhaps pre-glacial) slides, affecting a former escarpment of the soft rocks, along the base of which the stream was working. Part of the irregularity is certainly attributable to this cause, but I am inclined to believe that there is as

Disturbed strata.

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well some faulting parallel to the line of the stream, or that the softer beds have here been crushed by pressure, at their line of contact with the more resistant old rocks, as so often occurs.

At the point where the principal openings were made, the lignite and associated shales were found to dip S. 55° W. < 60° or even higher. A drift run in here for eighteen feet, passed through practically solid lignite for nearly that distance, when shales and sandstones dipping in an opposite direction, at an angle of about 45°, were encountered. As it is scarcely probable that the lignite here occupies so narrow a synclinal fold, it is likely that it is either slipped or faulted down to the eastward on the shales and sandstones found at the end of the drift.

The stream and the exposures along it, are here close to the east side of the wide valley, the floor of which slopes gradually up westward to the base of the Clear Mountains. The slope thus formed is lumpy and irregular in detail. This is probably due in part to old landslides, in part to morainic accumulations and irregularly disposed drift materials, with which the surface is in general covered. The stratified Tertiary rocks are scarcely seen in place, but they are frequently represented, for nearly two miles, by yellowish soft shales, poached up and disturbed, but evidently not far moved. The highest appearance of such materials noted, was at about 650 feet above the level of Hat Creek, and on the assumption that the beds are in the main horizontal, the thickness of the sedimentary beds must be at least thus great. A little higher up, thick beds of vesicular basalt are found capping the softer materials and running back to the steep base of the Clear Mountain range. The rocks composing this part of the range are granites, and to the north of Limestone Creek the volcanic materials were observed to rest directly on these by overlap. The surface of the granite is here somewhat decomposed and soft, and slopes toward the valley at an angle of nearly 20°. The rock actually in contact with the granite, at one place, was found to be a melaphyre, with well marked flow-structure and including in its mass numerous small fragments picked up from the granite.

The basaltic flows have probably at one time entirely covered the sedimentary Tertiary rocks of this part of Hat Creek valley, for extensive remnants of them occur at nearly corresponding elevations on the opposite or east side, where they form a step-like border to the Paleozoic rocks of the higher hills.

The sedimentary rocks here observed, in their general appearance and in the conditions of their occurrence, closely resemble those already

Measures probably regular west of Hat Creek.

Basalt capping.

Other basalt remnants.

Age of sedimentary beds.

described on Guichon Creek (p. 192 B). They were not observed to contain any contemporaneous volcanic materials, and it is highly probable that they are referable to the Coldwater series of the classification adopted in this report. No determinable organic remains have been found in them.

Relation to
beds of lower
valley.

The natural exposures do not serve to satisfactorily connect the sedimentary beds of this part of Hat Creek valley, with the conglomerates and sandstones of the lower part of the valley, which undoubtedly represent the Coldwater beds; a gap of more than a mile occurring between them, for which there is no information. While it is possible that the two areas are continuous along the bottom of the valley, it has been thought better to represent them on the map as being disconnected. It is believed, however, that the beds seen on the upper part of Hat Creek represent the higher parts, while those on the lower part of the creek represent the lower parts, of a single series of Tertiary deposits. The conglomerates were nowhere seen in place in the upper part of the valley, but large, loose pieces of conglomerate, identical with that of the lower valley, were found some miles above the lignite outcrops on the creek.

The Tertiary volcanic rocks, last seen at about a mile and a half below the bend made by Hat Creek at the entrance to Marble Cañon, are basalts, apparently brecciated, underlain by purplish melaphyre identical with that described as overlying the granites near the mouth of Limestone Creek, and probably an extension of the same flow.

Character of
lignite.

In regard to the composition of the lignite here met with, the following assay by Dr. Harrington may be quoted from the report of 1877-78 (p. 121B):—

Water.....	8.60
Volatile combustible matter.....	35.51
Fixed carbon.....	46.84
Ash.....	9.05

For a lignite, the fuel is therefore of good quality, and the great thickness of the bed should render it of some importance, at least locally.

Site recom-
mended for
boring.

As a result of the observations made on the mode of occurrence of the lignite and its associated rocks, it would appear to be desirable to abandon further exploratory work in the disturbed measures near the eastern edge of the valley, and to make a test by means of a boring, put down at a distance of a quarter or a third of a mile to the westward of the locality on the stream at which work has already been

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done. From analogy with the Nicola Valley occurrences, it is quite possible that in beds beneath the lignite already known, fuels of the character of true coals may yet be found. Whether this is or is not the case in this locality, can be determined by boring only. It is further to be remembered, that the lignite-bearing rocks, if correctly referred to the Coldwater series, should here extend beneath the great volcanic accumulations of the Clear Mountains. This implies, that anywhere to the south of Limestone Creek, the mountains bordering the valley do not necessarily mark the limit of the lignite-bearing series in a westerly or southerly direction.

Possible
occurrence of
coals.

Before leaving this part of the Hat Creek valley, a word may be said respecting some possibly Pliocene materials met with in one place. These occur on the small stream which flows into Hat Creek opposite Blue-earth Creek, about a mile above its mouth. They consist of conglomerates, composed chiefly of well rounded basaltic pebbles, many of which are vesicular basalt. There are also some thin layers of dark gray sandstone made up of comminuted basalt. These materials are evidently water-bedded, and from the large proportion of basalt they contain, are probably later in date than the main period of volcanic activity. The thickness of these beds actually seen is about fifteen feet only, and their extent was not ascertained. They occur at an approximate elevation of 4500 feet, and dip, or slope, eastward, at a very low angle, toward the axis of the valley.

Beds regarded
as Pliocene.

To the south of Pavilion Creek, and high up on the shoulder of the mountain between that creek and the valley of the Fraser, a small patch of Tertiary sandstones was found. This has a greatest length of about three miles, and occupies a nearly level area of not more than a mile in width. Its general elevation is from 3000 to 3500 feet above the sea-level. The sandstones are gray on fresh fracture, weathering to yellow tints, slightly calcareous, and apparently composed of arkose material derived from the weathering of granitic rocks. They hold some thin conglomeritic layers, are nearly horizontal, and have probably a thickness of several hundred feet, though the greatest actually observed thickness was about 50 feet. Some shaly fragments, apparently referable to Tertiary rocks, are contained in them, and shaly or clayey beds probably occur in association with them; for where they come to the high edge of the Pavilion Creek valley, they have supplied the materials for a great, old landslide, which in a succession of wave-like ridges and mounds has covered the whole slope down to the level of the creek itself, near the Indian village. No volcanic rocks are associated with this outlier and we have no means at this place of deter-

Sandstone
area south of
Pavilion
Creek.

Old landslide.

mining its position in the Tertiary series; but in all probability, it may be considered as representing a part of the extent of the sandstone which is found underlying the basaltic plateau at a similar level, on the opposite side of the Fraser near Leon Creek (p. 216 B).

Tertiary out-
lier of Pavil-
ion Mountain.

Another Tertiary outlier, of larger dimensions, occurs on the opposite or north side of Pavilion Creek, covering a wide sloping area on the south-west flank of the Pavilion Mountains at 3500 to 4500 feet. Its area is characterized by flat land or by light undulating slopes, and is occupied by several good farms. It is thickly drift-covered, and in consequence its actual outlines are fixed only approximately and with difficulty. Loose blocks of yellowish sandstone, like that last described, were observed, while basaltic rocks were seen to form a scarped outcrop overlooking the valley of Pavilion Creek to the west of Capt. Martley's house. The Tertiary area is here characterized by a notably red soil, and it would appear that the immediately underlying beds consist of volcanic, and chiefly of basaltic, materials, derived from the crumbling surfaces of recently erupted rocks of that class, arranged in beds in some body of water which at the time covered the region. The relations of the yellowish sandstones, the basalts and the reddish superficial beds, were not definitely ascertained, but it is believed that the last-mentioned beds may be of Pliocene age, and possibly synchronous with the basaltic conglomerates already mentioned as occurring in the upper valley of Hat Creek. The actual elevations of the two places nearly correspond.

Section on
Lower Hat
Creek.

The lower part of Hat Creek, cuts obliquely across an area of Tertiary conglomerates and sandstones, which on the line of section has a width of about five miles (See section No. 6). The underlying rocks, on the side toward Marble Cañon, are chiefly limestones, those on the opposite or east side, chiefly cherty quartzites and dark argillite-schists. The Tertiary rocks form two main synclines, separated by a narrow projection of limestone and greenish felspathic rocks, which appears to be covered by the Tertiary rocks not far to the south of the valley, as represented on the map. The west edge of the Tertiary area, is found about three miles and a half below the bend made by Hat Creek at the east end of Marble Cañon, where the rocks overlapping the limestone consist of a conglomerate, chiefly composed of limestone fragments but also containing pebbles of chert and other rocks. The beds are firmly coherent, and weather reddish. To these succeed, in ascending order, a great series of sandstones and conglomerates, the materials of which have been for the most part derived from the cherty quartzites of the Cache Creek formation. The cement is calcareous, and the usual colours of

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the rocks greenish-gray, gray or brown. The conglomerates are sometimes lenticular, but on the whole the beds are extremely regular. They are nowhere very coarse. Shales seldom occur, nor were any tuffaceous or other beds of volcanic origin observed. The beds dip in most places at angles of 30° to 50°. The thickness of the entire series as here found is about 5000 feet.*

Thickness represented.

To the south of the line of section above described, the conglomerates and sandstones run for some eight miles, to the trail which crosses from McLean Lake to Medicine Creek. They form a high, broken, hilly country, of which the Trachyte Hills are the culminating point. The exposures are nowhere so good as those in the valley, but the lithological character of the beds continues the same, though the angles of dip are generally lower. The highest part of the Trachyte Hills, with an elevation of 5200 feet, is composed of a fine-grained homogeneous, white mica-andesite, showing foliation or flow-structure running in various directions through it.† It is not certain whether this forms an outlier of an old flow, capping the conglomerates, or whether it marks the site of a local eruption cutting through these beds.

Continuation southward.

Trachyte Hills.

South of McLean Lake, a small outlier of the conglomerates was found, in a rough, broken country heaped with morainic matter. Its precise extent remains indeterminate.

McLean Lake.

The small detached Tertiary outlier shown as capping Campbell's Hill, consists of brownish vesicular basalt.

Campbell's Hill.

A very small patch of Tertiary rocks, not more than a few acres in extent, occurs on the east side of the Bonaparte River about three miles and a half from its mouth, or two miles and a half from Cäche Creek. This lies on the sloping side of the valley and its bedding conforms to the slope. The lower beds are argillaceous and carbonaceous shales with whitish sandstones, and these contain one or two seams of lignite, never more than a few inches thick. The whole thickness of the stratified materials can not be much more than fifty feet. They are capped by basalt, somewhat irregularly columnar and about a hundred feet in thickness. The regular bedding of the stratified materials, shows that they must originally have been horizontal or nearly so. Their present inclination, at an angle of about 25°, must therefore be a true superinduced dip, if the whole mass is not the result of an old slide from the edge of a formerly wide-spread deposit, the rest of which has been removed. Some well preserved specimens of silicified wood occur in this outlier.

Small Tertiary outlier on Bonaparte.

* In part quoted from Report of 1877-78, p. 121 n. † Appendix I., No. 71.

Rocks to north
of Lower Hat
Creek.

To the north of the lower part of Hat Creek, the outlines of the western limb of the Tertiary rocks have been laid down almost entirely by means of distant bearings and sketches, obtained from the Trachyte Hills and from different parts of the Pavilion Mountains. The Tertiary rocks in this region, are sufficiently distinct in appearance from those of the Palæozoic, even at a distance. It is assumed that this area is characterized by conglomerates and sandstones, but it is at the same time possible that some part of it is occupied by volcanic rocks. What may be called the eastern limb, is somewhat better known. Where seen on the plateau between Hat Creek and Maiden Creek, it consists of sandstones and conglomerates. Where crossed on the line of Maiden Creek, the rocks are gray or greenish-gray sandstones and conglomerates, often in very massive beds and containing no shaly intercalations. Their thickness here is at least 500 feet. Further north, the same rocks are found to the west of Glen Hart, along which valley they appear in low mural cliffs. The last exposures of this kind were observed nearly abreast of the southernmost small lake in the valley. To the north of this point, the plateau-like area which has heretofore been occupied by the conglomerates and sandstones, is found to be covered by basaltic rocks, and it is not known whether the sedimentary rocks continue to underlie these. The level of this outlying basaltic plateau is from 1000 to 1500 feet above the Glen Hart valley.

Glen Hart.

Tail-tsalt'
Ridge.

The southern part of Tsil-tsalt' Ridge, between Glen Hart and the Pavilion Mountains, is capped by red-weathering volcanic rocks which are apparently chiefly basaltic. These rocks seem to slope down along the ridge to the southward, and on Maiden Creek, a small area of volcanic rocks was found to overlap the conglomerate and sandstone beds in horizontal layers. This is composed of hornblende-andesite.*

East side
Pavilion
Mountains.

To the north of the source of Pavilion Creek, a very small outlier of a whitish trachyte-like rock was found, patched upon the eastern slope of the Pavilion Mountains at a height of about 6500 feet above the sea. This may possibly be the same in composition as the andesite of the Trachyte Hills, which it resembles in appearance. It is foliated and dips eastward at low angles.

Hart Ridge.

The small Tertiary outlier which is shown on the map to occupy the northern part of Hart Ridge, must be regarded as very indeterminate in outline. Basaltic breccias were found at this place to cap the ridge, but the covering of drift materials is so thick, that it was impossible to ascertain how far southward such rocks may extend along

*Appendix I., No. 72.

the crest of the ridge, of which all the lower parts, on both sides, undoubtedly consist of much older rocks. Outcrops of schists found on the northern slopes of the ridge, show that these old rocks here occur to an elevation considerably greater than that of the base of the basalts on the neighbouring edge of the Green Timber plateau to the northward.

Small exposures of Tertiary sandstones, were seen in this vicinity at a much lower level, on the west side of Round Lake, in the northern entrance of the Glen Hart valley. It is possible that beds of this character may occupy a considerable area of adjacent parts of the wide Junction Valley, near Clinton, but this is entirely buried beneath drift deposits and later alluvium. The base of a sandstone deposit of this kind, occupying as it does the bottom of a great depression in the old schistose rocks, would appear to be a likely place in which to search for old Tertiary gold placers; but it might prove to be very difficult and expensive to reach and properly test it.

Round Lake
near Clinton.

Deposits possibly auriferous.

Tertiary Rocks to the West of Fraser River.

From the vicinity of Fountain Creek, nearly to Red Creek, the Fraser approximately follows the line of junction of the Tertiary volcanic rocks with those of the Cretaceous series, the line being in fact the northward continuation of that along which the Three-lake Valley is eroded. North of Red Creek, the Tertiary rocks begin to occupy a considerable area to the west of the river, and to the north and west of the present map-sheet, this area appears to become even more important.

Fountain to
Red Creek.

At the trail-crossing of Red Creek, purplish, gray, and greenish augite-porphyrates are found, and some of these rocks weather readily into crumbling slopes of bright red colour. From the crossing of Red Creek, as far as Leon Creek, the Tertiary volcanic rocks consist chiefly of gray, greenish, and purplish porphyrites, sometimes breccias. At the spring marked on the map, the rock is a hard fine-grained eruptive, probably a diabase-porphyrite, but not microscopically examined. Before reaching Leon Creek, basaltic rocks, rather sparingly seen further south, are found in nearly horizontal flows broken off at a considerable height above the river. The boundary between the Cretaceous rocks on the west, and the volcanic Tertiary rocks, is here remarkably distinct and straight, and follows a well-marked valley which is nearly parallel to that of the Fraser. There is some reason to suppose that this boundary may be a faulted one, but this is not certain.

Red Creek to
Leon Creek.

Leon Creek.

On Leon Creek, two miles and a half west of the Fraser, Tertiary porphyrites are again found to replace the Palaeozoic rocks, which here border the river. They are generally agglomerates, containing many amygdaloidal fragments and showing evidence of considerable disturbance. These volcanic rocks here appear to occupy the eastern edge of a basin, and, further to the west, beyond the limit of the map, similar rocks seem to form hills of some height.

Continuation of Clear Mountain axis.

Taken as a whole, the porphyritic rocks between Red and Leon creeks, appear to represent a continuation of those found in the Clear Mountain axis of eruption. On both sides of Leon Creek, they are capped by nearly flat flows of more or less distinctly columnar basalt, which when freshly broken has a purplish colour. These occupy a proximately level area of considerable extent, which breaks off at the edge of the great valley of the Fraser at an elevation of about 3000 feet, but which rises gradually to the westward, conveying the impression that the basaltic material flowed from that direction. About two miles and a half south of Leon Creek, where the basalts cap granitic rocks, a bed of sands was found to lie beneath the basalts in some places. The whole extent of this intercalation was not determined, but it is probably local. The sandstone is yellowish and rather soft, often coarse and sometimes pebbly. It is composed chiefly of angular granitic debris. (See p. 211 B.)

North of Leon Creek.

North of Leon Creek, basalts similar to those just described and forming an extension of the same flow or series of flows, continue to cap the high hills on the west side of the Fraser as far as the edge of the map-sheet. The last isolated patch of basalt shown, in this direction, is part of a very small outlier. Further to the west and north, the hills fall back from the Fraser in the vicinity of Watson Creek, porphyrites like those of Leon Creek are again seen in them, though the rocks immediately bordering the river are continuously Palaeozoic, nearly or quite to the mouth of Big Bar Creek.

Sources of basalt flows.

The remnants of old basalt sheets found high above the Fraser along this part of its valley, together with those of the head-waters of Big Bar Creek, probably represent flows of proximately local origin, and have proceeded from sources different from those which flooded the Green Timber plateau. In any case, their present appearance indicates a very great amount of river erosion since the date of their formation.

Tertiary Rocks of Big Bar Creek and the Green Timber Plateau.

South branch of Big Bar Creek.

The northern part of the valley bordering the Marble Mountains on the west, contains the sources of the south branch of Big Bar Creek.

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It is occupied by a long narrow strip of basalts, the surface of which generally slopes gradually to the westward from the base of the mountains. The whole valley is so much encumbered with drift material that little was seen of these basalts, but they appear to be of no great thickness. They probably connect with the basalts of the Green Timber plateau, round the eastern end of the Marble Mountains. Their southern termination, as shown on the map, is largely conjectural, on account of the complete mantle of drift in the vicinity. It is also possible that they may occur to some extent along the west side of the south branch of Big Bar Creek, though no evidence to this effect was obtained.

Between the source of the south branch of Big Bar Creek and Kelley Lake, two streams from the eastward enter the valley separating the Marble Mountains from the Edge Hills. Near the mouth of each of these streams, basaltic boulders were observed to be very abundant, and it is possible that small basalt outliers may occur in these depressions, on the flanks of the Marble Mountains.

The Green Timber plateau, of which the southern part is contained in the present map-sheet, being crossed from Clinton northward by the old Cariboo wagon-road, is one of the best known features of this part of the province. To the eye, as viewed from any higher point, it is level and sea-like, but that part of it included in the map, really slopes gradually and somewhat irregularly from a height of 4500 or 5000 feet, near the north-eastern base of the Marble Mountains, to one of about 3000 feet near the North Branch of the Bonaparte River. The greater part of this eastern descent occurs, however, near the base of the Marble Mountains, the eastern portion of the plateau being not far from level. The whole plateau is heavily covered with drift deposits, but rock is occasionally seen in place, and where this does not occur, large masses or angular boulders of basalt of a single kind, are often found grouped together in such contiguity as to indicate that this rock is in place in the immediate vicinity. Along the southern edges of the plateau, near Clinton and on the Bonaparte Valley, sections of the basaltic rocks also occur, and there can be little doubt that the entire area of the plateau is underlain by rocks of this character, though it is possible that these may have been cut through by the older rocks below in some places. The source or sources of these great horizontal or nearly horizontal flows of basalt, have not been determined, but their general contemporaneity with the basalts of Big Bar Creek, those of the vicinity of Leon Creek and the very widely extended areas of basalt and basalt-breccia to the south and east of the Green Timber plateau, can scarcely be doubted.

The Green
Timber
Plateau.

Fly Creek.

On the lower part of Fly Creek, a tributary of the Bonaparte which forms a small cañon before reaching that river, good sections of basalt are seen, and rocks of the same character occupy the whole depth of the Bonaparte Valley to within about a mile of the mouth of the North Branch, where they are found to be underlain by greenish tuffaceous sandstones, dipping about N. 45° W. < 40°. The sandstones are imperfectly exposed and their thickness is not known. They rest upon greenish diabase, which is referred, though with doubt, to the Nicola formation, but this is soon replaced by granitic rocks which characterize the lower country about the forks of the Bonaparte.

Bonaparte
east of Fly
Creek.

From Fly Creek eastward, nearly to the mouth of the Chasm, the Bonaparte Valley is similarly characterized by basaltic rocks, sometimes forming more or less distinctly columnar flows, sometimes rough breccias arranged in thick beds. These rocks frequently form mural cliffs along the higher slopes of both sides of the valley. Half a mile above the mouth of the Chasm, a small projecting point of gray schistose rock occurs. This is overlain by a considerable thickness—probably several hundred feet—of soft, white and yellowish tuffaceous breccia, which extends to the Chasm and beyond it, forming cliffs characterized by fantastic, mural and columnar forms. The matrix is a pale-gray mortar-like material, and this is studded with fragments, sometimes as much as two or three yards in diameter, which are generally angular and are chiefly volcanic rocks of various kinds. The smaller fragments appear to be more varied in origin, and are often partly rounded.

Tuffaceous
breccia.

The Chasm.

This breccia has evidently been deposited in water, and is fairly well stratified though the component beds are thick. At the mouth of the Chasm it overlies a mass of purplish decomposed porphyrite and is capped by basalts and basalt-breccias of the ordinary type. The remarkable cliffs of the upper parts of the Chasm, represent rocks which overlie the pale breccia. These are very well bedded, generally in layers not exceeding six feet in thickness, and most of the beds appear to represent volcanic muds or sands of a basaltic character rather than true eruptive basalts, though layers of the latter character also occur. The columnar appearance presented by the cliffs, is due chiefly to weathering along jointage planes and only in part to the development of a true basaltic structure. Bright yellow and red layers are conspicuous in the cliffs and the aspect of the whole is very picturesque and striking. A good general view of the Chasm, from above, is gained from a point on the Cariboo wagon-road near its bend. At this place, the basalt, in a borrow-pit on the road, includes

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numerous cavities filled with crystalline chabazite. The whole thickness of the volcanic rocks cut through in the Chasm must be over 1000 feet.

The plateau area to the north of the main valley of the Bonaparte and east of the North Branch, must be regarded as a portion of the Green Timber plateau, cut off merely by the erosion of the valley of the North Branch. The basaltic rocks come down to the bottom of the valley near the outlet of Young Lake, where they are represented by brownish, compact and vesicular basalt flows. Elsewhere the lower slopes of the Bonaparte Valley, in this part of its length, are characterized by granitic rocks, which appear to directly underlie the basalts.

Plateau east of North Branch.

Tertiary Rocks of the Bonaparte Plateau, the Arrowstone Hills and Adjacent Country.

The Bonaparte Plateau may be described as a southern extension of the Green Timber plateau, from which it is cut off only by the subsequently eroded valley of the Bonaparte. The basaltic rocks cut through by the Bonaparte Valley have already been noticed, and it is probable that the entire area of this plateau is characterized by similar rocks. It has been traversed only on the exploratory lines shown on the map, by Mr. McEvoy, who writes of it as follows: "Southward from the forks of the Bonaparte, the basalt begins at an elevation of 3400 feet, and continues on the line of route to Loon Lake valley. Along this valley, to the westward, and for two miles and a half along the north side of Loon Lake itself, is a blackish fine grained basalt, often amygdaloidal, containing chalcidony and other minerals. Further to the west, the lake-shore is composed of basaltic breccia and fine grained, dark-gray basalts showing well marked flow-structure."

Bonaparte Plateau.

The Arrowstone Hills, stand in the centre of a wide and generally plateau-like area, which for purpose of description may be limited to the northward by the Loon Lake valley, to the south by part of the Thompson Valley and to the west and east respectively by the valleys of the Bonaparte and Deadman rivers. The profile of the central parts of this area, seen from almost any bearing, shows it to possess a depressed dome-like form, the highest part of which includes the blunt summits of the Arrowstone Hills, reaching elevations of about 5700 feet. The whole form of the surface has of course been affected to a very considerable extent by denudation, but its general aspect seems to indicate, that the higher region of the Arrowstone Hills may represent the source from which much of the volcanic material covering this tract of country welled up.

Arrowstone Hills.

General form.

Rocks largely
basaltic.

A large part of this area is very inaccessible because of its thickly wooded character. It has, however, been traversed on several lines by Mr. McEvoy, from whose observations it would appear that probably eight-tenths of its entire surface is occupied by basaltic rocks, either in the form of flows or in that of basalt-breccias, often very uniform in composition and appearance for long distances. Volcanic rocks of other kinds observed, are chiefly those of the higher parts of the Arrowstone Hills and those found underlying the ordinary basaltic materials where these have been cut through. Thus, in respect to this area, attention has been chiefly directed to ascertaining the outlines of the Tertiary volcanic rocks as a whole, rather than to any detailed examination of different parts of the plateau.

Possibly older
eruptions.

It is quite possible that some of the rocks met with, particularly those of parts of the Arrowstone Hills themselves, should be classed with the older Miocene eruptives, like those found in the Clear Mountains and on the Nicola Valley, but as there is no means of determining this point, it has been thought best to include the whole of the mass with the later eruptives, to which by far the greater part, at least, certainly belong.

Notes on
routes tra-
versed.

The subjoined notes by Mr. McEvoy, relate to the routes actually traversed by him and shown upon the map. "The southernmost main elevation of the Arrowstone Hills, lies between the two branches of Cache Creek and the sources of Scottie Creek. In ascending from the forks of Cache Creek, purplish porphyrite is found, and rocks of a somewhat similar character are abundant on this slope. In the higher part of the hills they become very hard and tough, and much resemble some rocks seen on the north slope of Mount Glossy. Some of these rocks are distinct augite-porphyrates. On the north side of this group of hills, which slopes down to Scottie Creek, there is an exposure of very fine-grained augite-porphyrite, resembling obsidian, associated with basalt*"

Obsidian-like
rock.

The obsidian-like rock above mentioned, is very common in loose boulders and fragments everywhere in the vicinity of the Arrowstone Hills. It was formerly employed by the Indians for the manufacture of arrow- and spear-heads, and probably occurs in considerable volume in the higher parts of the Arrowstone Hills.

Hyalite.

"Crossing Scottie Creek and ascending the hill to the north, the country is deeply drift-covered. The top of the hill is generally composed of dark brownish basalt, often highly vesicular. On a summit one mile south of Hi-hium' Creek, this holds hyalite, both in the vesicles and between the layers of flow-structure. The extent of the area in

*Appendix I. No. 74.

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which the hyalite was observed to occur, is about one mile by half a mile, and some very fine specimens of this mineral, now in the museum of the Geological Survey, were obtained."

"No exposures were found about the crossing of Hi-hium' Creek, but on the slopes of the hills to the north, vesicular basalt again occurs. The higher parts of these hills are composed of basaltic rocks* similar to those already noticed in connection with the southern summits of the Arrowstone Hills. No exposures were found on the north slope, in descending to Loon Lake, but the rocks are evidently basaltic."

The valley of the Deadman River, with a general course from north to south, connects the Bonaparte Valley with that of the Thompson, and forms the eastern boundary of the region now under description. "From the source of its north-western branch as far as the mouth of Criss Creek, a distance of more than twenty-two miles, it forms a deep narrow trough, which cuts through the Tertiary volcanic materials and exposes the underlying rocks of the Nicola formation nearly throughout, though in one or two places the Tertiary crosses the line of the valley. North of the mouth of Criss Creek and as far as Deadman Lake, soft white tuffaceous ash-rock is found exposed in vertical cliffs, with a maximum observed thickness of 500 feet, the bases of the cliffs being generally buried by slopes of talus. The talus seems in some places to consist of deposit of Tertiary conglomerate resembling that of Copper Creek. Between the mouths of Criss and Gorge creeks, numerous loose masses of such a rock were found. Overlying the tuffaceous beds are basaltic breccias, with a thickness of some 800 feet, and capping these, at the level of the plateau, are flows of brown basalt."

Deadman
Valley.

Massive
tuffaceous
sandstones.

The tuffaceous rocks above referred to, are in some specimens almost entirely composed of fine-grained felspathic matter of volcanic origin, but they generally include a certain proportion of arkose material with angular or sub-angular quartz grains. In some specimens the quartz grains become very abundant and a large part of the whole mass appears to be of an arkose character, derived from the decomposition of granitic rocks.

Arkose
material.

Along the west side of this area of plateau, the Tertiary rocks come down to the bottom of the Bonaparte at one place only, opposite the mouth of Hat Creek. They consist here of basalt-breccias and basalts. So far as ascertained, similar rocks appear to prevail in outcrops which occur high up on the sides of the valley. The Tertiary volcanic rocks outcropping on the south side, in the vicinity of the great trough now occupied by the Thompson River, have already been in part noticed in

Parts of
Bonaparte
and Thompson
Valleys.

* Appendix I, No. 73.

the description of the general section from the Bonaparte to Copper Creek (pp. 217 B, 218 B). Along the north side of the Semlin Valley, the volcanic rocks of the plateau are broken off in bold escarpments and cliffs. These have not been examined in detail, but they include both basalts and other materials of a less basic character, all arranged in massive layers and passing to reddish colours.

Near Eight-mile Creek.

The summit of the plateau to the west of Eight-mile Creek, in the angle between the Eight-mile Creek valley and Pass Valley, was found by Mr. McEvoy to be capped by dark-brown basalt containing very numerous crystals of magnetite, underlain by a volcanic breccia with a yellowish, earthy matrix. Near the mouth of the gorge of Eight-mile Creek, just above the wagon-road in the Thompson valley, a white, banded, felspathic rock, probably a trachyte, with very fine lamination produced by flow-structure, was noted by Mr. McEvoy. The rocks seen along the Pass Valley, are all referable to the Tertiary volcanic series. Basalt-breccias and breccias charged with fine-grained augite-porphyrates resembling obsidian, being the most abundant.

Connection with Savona Mountain.

Apart from the somewhat peculiar rocks of the higher portions of the Arrowstone Hills, the Tertiary volcanic materials of this plateau generally closely resemble those of Savona Mountain and the plateau attaching to it, from which they have indeed been divided only by the deeply excavated valley of the Thompson River.

Tertiary Rocks East of the Deadman Valley and North of Kamloops Lake.

Near Bonaparte Lake.

The Rim Hills, north of Bonaparte Lake, are capped by basalts in the manner shown on the map. These appear to rest directly on the granites of the region, but they have been laid down from bearings and distant views only.

The small outlier of Tertiary shown to occur to the north of the east end of Bonaparte Lake, was ascertained by Mr. McEvoy to consist of amygdaloidal basalt and brown dolerite.

The Kuk-waus' Plateau, the Sil-who'i-a-kun Plateau, the western part of the Tranquille Plateau and Red Plateau, together form portions of a single great area characterized by a wide spread of Tertiary volcanic rocks. This it will be convenient to consider briefly from north to south, in the order above indicated.

Kuk-waus' Plateau.

The Kuk-waus' Plateau, may be regarded, for purposes of description, as bounded on the south side by the upper part of the main stream of Deadman River and Hi-ak'-wa Lake. It has undoubtedly at one time

been entirely covered by horizontal flows, which have also, in all probability, extended across the hollow now occupied by Bonaparte Lake and connected, beyond the Bonaparte River, to the north-eastward, with the basalts of the Green Timber plateau. The surface had here, as elsewhere in this region, been worn down to an approximate equality in elevation before the date of the eruption of the basalts, the base of which is now found at a height of about 4500 feet on both sides of Bonaparte Lake, at about 4000 feet along the south side of the Bonaparte Valley near Young Lake, and at about 4600 feet near Granite and Hi-ak'-wa lakes.

Levels of base
of basalts.

The rocks underlying the basalts of the Kuk-waus' Plateau, are generally granitic, but on the south side of the plateau older stratified rocks also occur. No evidence of the existence of any bedded Tertiary materials beneath the basalts, has been found in this region, and if any such occur they must be local and not of great thickness. The basalts of this plateau are generally gray or brownish in colour, so far as observed, and offer no points of particular interest. They are occasionally vesicular, but not often columnar, except toward the east end of the plateau, where this structure is more usual. Seen from Bonaparte Lake, they form flat cappings to the higher granitic hills, and as observed from the summit of Skoatl Point, the various, and now more or less disconnected remnants, of the basalt flows, run together in the distance to form an almost perfectly level horizon-line. The western part of the northern outline of the basalts of Kuk-waus' Plateau, as shown upon the map, must be regarded as approximately correct only. All this region is covered with fallen timber and is very difficult to traverse.

No sedimentary
beds seen.

Character of
basalt flows.



FIG. 6. SKOATL POINT FROM THE WEST, ABOUT A MILE DISTANT.

Skoatl Point, is a small volcanic outlier standing near the eastern Skoatl Point, margin of the Kuk-waus' Plateau, from which the basaltic flows, doubtless at one time surrounding it, have been stripped away, leaving a tract of undulating hills composed of granite and old altered rocks, now

more or less covered with drift deposits and dotted with lakes. From this, Skoatl rises very abruptly, with a steep conical form—somewhat narrower in its north-and-south than its east-and-west diameter. It affords a magnificent view of the frayed eastern edge of the basaltic plateau for many miles, and is itself a prominent and easily recognized point, which may be picked up from the summits of the higher mountains often at a distance of fifty miles or more. It is composed of a somewhat coarse-textured, dark-gray olivine-basalt, with a finely developed columnar structure.* The columns average about a yard in diameter, and are curved in several directions, but with a general tendency to meet toward the apex of the hill. Those on the west side run from base to summit with a gentle sweep. There is every reason to believe that Skoatl represents the plug of an old vent, from which much of the basaltic material of the vicinity may have flowed out.

Sil-whoï'-a-kun plateau.

The name Sil-whoï'-a-kun, though more restricted in its application by the Indians, may be employed in the present connection to designate all that part of the plateau to the south of that last described and to the north of Tranquille Lake. This is almost entirely covered with basaltic rocks. The rocks of its western edge, as they occur along the Deadman River, have already been noticed (p. 221 B). In the part of the region drained by Criss Creek, and along the upper valley of that creek, the rocks seen are all ordinary gray or brown basalts, often forming several superposed flows and occasionally columnar.

Near Caribou Lake.

In the valley in which Caribou and Tsin-tsoon'-ko lakes lie, the sheet of volcanic rocks has been cut through locally, exposing an isolated area of Palaeozoic rocks and granite. The basalts found in this vicinity are gray and blackish, not often vesicular, and seldom distinctly columnar.† Poison Hill, is a rather prominent bold spur of the eastern edge of this part of the basaltic area, rising nearly 300 feet above the low land at its base. It is chiefly composed of rudely columnar basalt, more or less amygdaloidal, with the vesicles filled with zeolitic minerals, but is capped by a similar blackish basalt with a laminated appearance due to nearly horizontal flow-structure.

Dome-like form of plateau.

As seen from a distance, particularly in a general view obtained from the summit of Pavilion Mountain, the whole of this part of the plateau rises gradually to a wide dome-like form, of which the highest part is in the vicinity of Porcupine Ridge, in a manner highly suggestive of the belief that a great part of the basalts of the surrounding flowed out from this as a centre. (Compare p. 219 B.)

* Appendix I., No. 78.

† Appendix I., No. 77.



FIG. 7.—EASTERN ESCARPMENT OF BASALTIC ROCKS.

As seen looking northward from Poison Hill. Vertical shading indicates the basaltic rocks.

The highest portion of the base of the basaltic flows is likewise found near Porcupine Ridge and Basalt Point of the map, at elevations of 5490 and 5400 feet respectively. From this vicinity, the level of the base of the volcanic materials declines northward to that already referred to near Hi-ak'-wa and Granite lakes, westward to about 3000 feet on the lower part of Criss Creek, and southward to even lower levels in the vicinity of Kamloops Lake. No trace of Tertiary sediments underlying the basaltic flows was found in this region, except as already noted along the Deadman River at its western end, but it is seldom that the exposures are so good as to enable it to be stated definitely that beds of this kind of small thickness may not occur.

The most elevated part of the entire Sil-whoï'-a-kun Plateau is that at and near Porcupine Ridge, where the height attained is about 6000 feet. The summit of Porcupine Ridge, though broken by numerous minor irregularities, is in the main nearly horizontal. To the south it is broken off abruptly toward the deep valley in which Tranquille Lake lies. The rocks composing the ridge are chiefly olivine-basalts of dark colours, verging on black, and often lumpy and irregular in consequence of a fragmental or concretionary structure—probably the latter.* Some ordinary gray basalt was also found, and in two or three places areas of coarse brownish hornblende andesite with a lamination produced by flow-structure which dips at various angles irregularly.† The best marked occurrence of this rock is that forming a partly detached hill on

* See Appendix I, No. 63.

† See Appendix I, No. 64.

the south slope, and this, as seen from the opposite side of the valley, much resembles the filling of an old vent or fissure of eruption. On the western flanks of the more massive rocks comprising the ridge itself, basaltic strata, often columnar, are seen, from the south, to rest upon the rocks of the ridge and to slope away from them as a centre.

A probable
vent.

These and other circumstances tend to show that Porcupine Ridge marks the site of one of the more important local sources of the great basaltic eruptions of the later Miocene.

At the junction of Criss Creek with the Deadman River, the plateau runs out in a narrow and remarkable bold point which may be called Split Rock. This is chiefly composed of rough basalt-breccia and is traversed in one place by a deep open fissure with vertical walls.

Tranquille
Plateau and
vicinity.

To the south of the region above described, is a large area of plateau chiefly drained by branches of the Tranquille River, of which the volcanic rocks of the Tertiary cover the greater part, as far south as Kamloops Lake. To the south of Criss Creek and west of Porcupine Ridge, a considerable district of this part of the plateau has not been examined on the ground. It is densely wooded or covered with fallen trees, but its contour, as seen from various points of view, and the margins of the volcanic rocks which have been defined, indicate that it is probably occupied in the main by ordinary basalts. The great quantity of large and small boulders of olivine-basalt* met with in the valley of the Tranquille some miles above the fall, however, shows that a considerable area of rocks of this character must occur to the west of Porcupine Ridge.

Near Lower
Criss Creek.

The summit of the plateau in the angle between Criss Creek and the Deadman River, on the east, at elevations of 3000 to 3500 feet, is composed of blackish, basaltic rocks, sometimes very rich in olivine, but is so much covered with drift that they are seldom seen in place and their precise extent, particularly to the eastward, remains doubtful. After crossing the continuation of the cherty conglomerates of Copper Creek, the country, to the Tranquille Valley, is chiefly characterized by basalt flows, both on the line of traverse by way of the Red Lakes and on that from the head of Copper Creek, but on both routes much of the ground is covered by drift.

Upper Tran-
quille Valley.

In the Tranquille Valley, a couple of miles above the fall, a white dacite† was found to form the lower slopes for 200 to 300 feet above the level of the stream. Overlying this are basalts and basalt-breccias to the level of the plateau on both sides. Following the valley down,

*Appendix I., No. 76.

†Appendix I., No. 70.

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the dacite appears to extend nearly as far as the fall, but with this exception, the rocks seen on both sides are almost entirely basaltic, and chiefly consist of basalt-breccias, to the mouth of Watching Creek. The beds composing these are more or less lenticular, but the aggregate thickness is well preserved. They are nearly horizontal and frequently produce steep scarps and cliffs, which resemble both in their appearance and composition those met with to the north of Battle Bluff (p. 172 B) of which the beds seen here are the continuation. Near the mouth of the stream which comes in from the north side of Mara Hill, these rocks are underlain by the soft, yellowish, tuffaceous agglomerates, forming part of the subdivision designated as No. 6 in the Kamloops Lake section (p. 165 B).

On the trail which runs eastward from the main valley of the Tran- Middle Fork
quille, crossing the Middle Fork and Watching Creek some distance and Watching
above their confluence, similar basalts and basalt-breccias are seen; but Creek.
where this trail crosses the Middle Fork, exposures of soft, yellowish, tuffaceous agglomerates, charged with fragments of brittle tachylite (?) and evidently representing those above referred to subdivision No. 6, are met with.

From this point, a traverse was made up the Middle Fork and to Plateau south
the south side of Tranquille Lake. The summit of the plateau here of Tranquille
has an elevation of from 4500 to 5000 feet, and is more varied in the Lake.
detail of its topography than might be supposed from distant views of it. The basaltic flows of which its whole upper surface appears to be composed, frequently form low plateau-like hills with steep broken edges. The rocks seen were basalts and olivine-basalts.*

Along the upper part of Watching Creek, the volcanic capping of the plateau appears to have been entirely removed by subsequent processes of erosion, and the stream flows over surfaces of the old Palaeozoic rocks. From high points on its eastern side, it is evident that the base of the Tertiary volcanic rocks slopes gradually southward, and at about two miles above the entrance of the valley in which Pass Lake lies, they come down to the bottom of the Watching Creek valley. Below this point, Watching Creek, and the Tranquille River into which it flows, nowhere cut down to the base of the Tertiary; and the comparatively thin covering of basaltic materials which occupies much of the plateau further to the north, in the vicinity of Kamloops Lake, is increased till it forms the series which has already been described in connection with the section in the vicinity of this lake (p. 173 B). It is thus evident, that near the present position of the lake, an original

Tertiary base
sloping toward
Kamloops
Lake.

*Appendix I., No. 75.

An original depression.

depression existed at the time in which the Tertiary sediments and volcanic materials were accumulated. This conclusion, resulting from the constitution and thickness of the Tertiary rocks as a whole, is independent of any later change in relative elevations which may have tended still further to depress the country in the vicinity of the lakes. To the east of the lower part of Watching Creek, the level of the surface of the old rocks upon which the Tertiary was deposited, also rises rapidly, as will be apparent on comparing the level of the northern part of the Garde Lafferty (with its small outlying patches of conglomerates) with that of the bottom of the lower part of the Tranquille Valley.

Hill of pikrite-porphyrity.

The hill to the east of Watching Creek and north of Pass Lake, which was ascended and examined, is chiefly composed of pikrite-porphyrity, blackish, greenish and greenish-gray in colour, and presenting a peculiar spotted appearance. These are capped by blackish basaltic rocks. Opax Hill was not ascended, but it appears to be composed chiefly of basaltic materials about its summit, while rocks of the same character as those just noted may probably occur in its lower portions.

The small detached area of Tertiary volcanic rocks shown to the east of Watching Creek, occurs in a tract of country rendered almost impassable by windfall. It was not actually reached, but from the character of the numerous loose masses found to the south of it, is believed to consist entirely of basaltic rocks.

Tertiary Outliers in the Vicinity of the North Thompson River.

Indian reservation on North Thompson.

Basin of sedimentary rocks.

Its area.

The most important of these detached areas of Tertiary rocks, is that near the Indian village and reservation at the extreme north-east angle of the map. This was particularly examined in 1877, because of the occurrence of coal in it. The Tertiary rocks here occupy a portion of the trough of the North Thompson, and are bounded on both sides by the old rocks of the higher hills. The amount of drift in this part of the valley is very great. On the east side of the river, a few exposures occur of sandstones and shales, particularly along the small stream named Coal Brook, but it is impossible precisely to define the area occupied by these rocks, which can be approximated to only on the assumption that they characterize the lower parts of the valley where the old rocks are not seen. On this assumption, the whole length of the Tertiary area to the east of the river cannot exceed five miles, while it may be much less. On the west side of the river, the only Tertiary rocks seen are gray and brown basalts, which occur quite down to the river-level nearly opposite the Indian village, and were also found on

the lower slopes of the hills on that side to a maximum height of 620 feet above the river.

The sedimentary beds in which the coal occurs, may of course underlie some part of the area in which only basalts are seen at the surface. A trifling amount of exploratory work has been done in recent years in the immediate vicinity of the coal outcrops at Coal Creek, but no addition has resulted from it to our general knowledge of the section, and it is improbable that any material addition to this knowledge will occur till boring operations shall have been undertaken. The sandstones and shales show no traces of volcanic material in their constituents, and it is probable that they represent an area of the Coldwater series of the Tertiary, as previously defined. The basalts are probably referable to a much later date.

Occurrence
coal.

Boring
necessary.

The following description and section of the beds is quoted from my report of 1877 (pp. 113 B-114 B.)

Description of
the measures.

"The area of this outlier, in so far as it can be defined by the section on the east bank of the river, is not great. It rests on the older crystalline rocks, forming a ridge about 600 feet high along the base of the tier of mountains which, rising to a height of 2000 to 3000 feet above the river, here forms the border of the valley. The length of the ridge is about two and a half miles, and it is where the little stream called Coal Brook cuts through it, that the Tertiary rocks are exposed, by the removal of the thick covering of boulder-clay and drift, which elsewhere shrouds it. The beds appear to form a syncline, nearly parallel in its main direction with the trough of the valley.

"The following section, in descending order, includes nearly all the beds seen in the brook channel. Some layers were measured, others estimated by the eye only:—

	Fest.	In.
1. Sandstone, soft.....at least	2	0
2. Carbonaceous shale.....	0	6
3. Shale and sandstone.....	3	0
4. Coal, shaly.....about	1	3
5. Hard clay.....	0	6
6. Soft shale.....	1	3
7. Gray, fine shale, with fossil leaves.....	2	0
8. Coarse- and fine-grained sandstone.....	15	0
9. Hard, fine, gray clays.....	1	0
10. (Concealed).....	10	0
11. Sandstone.....	2	0
12. Gray shales.....	3	0
13. Sandstone.....	2	0

	Feet.	In
14. Soft, gray shale.....	1	5
15. <i>Coal</i>	1	2
16. Shale.....	0	2
17. Sandstone and shaly sandstones.....	9	0
18. <i>Coal</i>	1	5
19. Black shale } irregular.....	0	8
20. Gray, crumbling sandstone.....	4	0
21. Carbonaceous shale.....	1 in. to	0 4
22. Rusty, nodular sandstone.....	1	8
23. Soft sandstone in thin layers.....	8	0
24. Concealed.....	15 feet to	20 0
25. Sandstone.....	4	0
26. Black shales.....	0	6
27. Sandstone.....	0	10
28. Shale, more or less carbonaceous, with a little coal.....	4	0
29. Ironstone, nodular.....	0	3
30. Thin-bedded clays, grayish and brownish.....	2	8
31. Gray sandstone, generally coarse and rather soft..	10	4
32. <i>Coal</i> , shaly.....	0	2
33. Brownish, sandy clays.....	6	9
34. Thin-bedded sandy clays, rather hard.....	about 20	0
35. Coarse, pebbly sandstone.....	about 8	0
36. Brownish-gray sandy clay, at base.....	..	..
	148	1

Dips

"At the base, the beds dip at an angle of 12°, further up at 15°, and again begin to dip at a lower angle at the summit. The direction of dip varies from N. 56° E. to N. 26° E. The lowest beds are first met with in ascending the brook. Beyond the highest represented in the above detailed section, a considerable gap occurs, in which the banks show no exposures. When next seen, the beds are poorly exposed, but one bank shows about twenty feet of sandstones and shales like those before met with, and includes two small seams of coal, the lower seven inches, the upper nine inches in thickness. These beds are doubtless the highest found in this locality.

"It would appear, however, that in the sections, but a small portion of the entire thickness of Tertiary beds represented at this place, is seen. Their general character is much like that of those of other localities in the southern part of the province, the sandstones holding, perhaps, more coarse pebbly material than usual. Notwithstanding this, however, there is no appearance of tumultuous deposit, and the coal-seams, though thin, show considerable regularity. The coal-bearing character of the formation appears to persist throughout the section, and a further examination by boring may at some time become desirable.

Site for boring.

The best locality for a bore-hole would probably be in the valley of the brook, at the lowest beds of the section."

In 1892, Mr. McEvoy revisited this locality and gives the following note concerning it :*

Later work
on coal.

"While in the neighbourhood an opportunity was afforded of visiting the coal mine on the North Thompson Indian Reserve. A tunnel running northward from the creek bed showed the following section :—

Coal.....	6 inches.
Sandstones.....	2 feet (variable.)
Coal.....	9 inches.
Sandstone.....	6 "
Coal.....	18 "

"Besides these an underlying seam of coal is reported."

The quality of the coal found here is good, and if thicker seams can be found, it would possess an immediate economic importance; on proximate analysis, it yielded the following results to Dr. B. J. Harrington :†

Quality of
the coal.

	Fast Coking.	Slow Coking.
Hygroscopic water.....	2.22	2.22
Volatile combustible matter.....	38.10	32.05
Fixed carbon.....	46.76	52.81
Ash.....	12.92	12.92
	100.00	100.00
Coke.....	59.68	65.73
Ratio of volatile to fixed combustible, 1 :	1.23	1 : 1.65

"Fast coking gave a bright and firm coke, which on burning away left a reddish-white ash. By slow coking the powder was agglutinated only in the bottom of the crucible."

A few fossil plants obtained from the above section in 1877, are thus described by Sir J. Wm. Dawson :‡ "The leaves from this place, in a matrix of gray arenaceous shale, are almost exclusively poplars, referable to *Populus arctica*, *P. genatrix*, Newberry, and another species. With these is a species of *Rhus*, allied to *R. rosaeifolia*, of Lesquereux."

Fossil plants.

The Tertiary outlier of Skull Hill, further down the North Thompson, consists, apparently, wholly of basalts and basalt-breccias, which seem to have locally a thickness of 500 feet or more and may rest directly upon the older rocks.

Skull Hill
outlier.

* Summary Report of the Geological Survey Department, 1892, p. 10.

† Report of Progress, Geol. Surv. Can., 1876-77, p. 467.

‡ Trans. Royal Soc., Can., vol. I., sect. IV., p. 34.

Other small
outliers.

The next small outlier to the southward, on the opposite or east bank of the river, consists of blackish fine-grained basalt. On the same side of the river, four miles still further south and near Sullivan Creek, a very small outlier of basalt was seen from below to be patched upon the granitic rocks there prevalent. Its precise outlines to the east and north have not been fixed.

Dome Hills.

A somewhat larger patch of Tertiary rocks, appears to the south of Edwards Creek on the northern slopes of the Dome Hills. This consists of several superposed flows of basalt, rich in olivine. It is often vesicular, holding chalcedony, or showing small quartz-lined cavities. Its eastern outcrop is rather obscure, but to the west it breaks off in an escarpment, along the base of which several springs rise. The occurrence of those springs may indicate the existence of some permeable underlying sedimentary materials, but no exposures of such rocks were found.

Tertiary Rocks to the South of Kamloops.

Basaltic out-
liers near
Kamloops.

The Tertiary rocks of this vicinity have already been noticed, as far as the coal locality marked on the map (p. 168 B). Immediately to the south of this, in the vicinity of Peterson Creek, the granitoid rocks are capped by several small basaltic outliers which are generally situated near the 3000-foot contour-line, but are not strictly confined to any particular level, resting as they do upon sloping surfaces of the older rocks. The apparent low dips by which they are affected, may probably represent the original inclination of the flows. At the road-crossing of Peterson Creek, these rocks are found at a rather lower level than usual and form a somewhat prominent little hill. The basalts are generally blackish or gray, and of the ordinary type. Their thickness is not great, and they appear to rest directly upon the granitoid rocks, and to lie altogether beyond the margin of the old depression in which the water-bedded materials holding the coal have been laid down.

Area between
Separation
Lake and
Stump Lake.

A much more important Tertiary area, with which the outliers just noticed have evidently at one time been continuous, is that which runs southward from the vicinity of Separation Lake to the head of Stump Lake, with a length of thirteen miles and a half and a maximum breadth of about six miles. The northern part of this area appears to consist entirely of basaltic flows of the usual character. The eastern edge of the volcanic rocks generally forms a well-marked escarpment at an elevation of about 3000 feet, overlooking the long

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valley in which Shumway and Trapp lakes are situated, but to the westward, the level of the plateau rises gradually, though irregularly, till the basalt rocks are found in some places at heights exceeding 4000 feet. In this region, to the north of the head of Moore Creek, the edge of the basalts often ceases to be marked by a distinct escarpment, and as the country here becomes thickly wooded their boundary is drawn with less precision than elsewhere.

The southern part of the area is characterized by a greater thickness, as well as by a somewhat greater diversity in the character of its volcanic rocks, for while basalt flows still occupy most of the surface, a series of pale felspathic rocks, which here comes in beneath them, is found in a number of places. Rocks of this character were seen further north, about half a mile west of the head of Brigade Lake, where they are represented by a fine-grained purple-gray material now much silicified, shattered and very hard. They are also abundant on the lower part of Dropping-water Creek and about the south end of Napier Lake, where the most characteristic form is a white quartz-mica-porphyrity, which occasionally becomes a fine-grained felspathic rock without defined macroscopic characters.

Underlying
pale felspathic
rocks.

These rocks are here probably 200 feet in thickness or more, and to the west of Napier Lake, and near the north end of Stump Lake, they appear to rest directly upon the irregular surface of the Nicola formation. About the south end of Napier Lake, they are overlain by massive basalt-breccias with at least a similar thickness, which in some places, by the rounded character of the basalt fragments, seem to indicate a certain amount of contemporaneous water-action. These are seen to occupy a well marked syncline which runs in a north-westerly direction from the south end of Napier Lake, and the series is probably affected by several low flexures of this character in that vicinity. The basalt flows previously described are believed to be later in date than the basalt-breccias.

Overlying
basalt-breccias.

On Dropping-water Creek, about two miles above the road-crossing, on the west side of the valley, pale brownish and gray felspathic rocks of the underlying series stand out in a rather remarkable cliff, which is traversed by several great open fissures. Small irregular cavities in this rock are filled with opaline silica, which in some specimens approaches the condition of precious opal so closely, as to warrant the conjecture that this mineral may yet be found in the vicinity. Similar occurrences of opaline silica were noted in other exposures of the pale-coloured rocks in this particular region.

Dropping-
water Creek.

Fossil plants.

Also on Dropping-water Creek, between the point last mentioned and the road-crossing, fragments of a fine-grained, silicified, shaly rock are abundant, in which some plant remains occur together with a few poorly preserved specimens of insects. These peculiar rocks were scarcely seen in place, but must underlie some part of the valley in this vicinity, and in all probability are to be found beneath the pale felspathic materials. Their position is approximately indicated on the map.

The following species of plants have been recognized in the collection from this place, by Sir J. Wm. Dawson and Professor D. P. Penhallow* :—

Azollophyllum princevum, Pen.; *Pinus trunculus*, Dn.; *Acerites negundifolia*, Dn.; *Carpinus grandis*, Ung.; *Carpolites dentatus*, Pen.; *Sequoia*, Sp.; *Glyptostrobus*, Sp.; *Acer* (Fruit).

At McDonald's, between Trapp and Napier lakes, twenty feet or more of sedimentary material is actually seen beneath the basalt-breccia. This consists below of gray arkose sandstone, above of brown earthy material with seams of coaly matter two or three inches in thickness.

Eastward of Stump Lake, the basalt-breccias of Dropping-water Creek continue for two or three miles, beyond which they are covered by black and brown basalt. The basalt here reaches an altitude of 4200 feet.

Possible occurrence of coal.

It may be added, that the circumstances connected with the southern part of this area of the Tertiary, appear to render it probable that some thickness of ordinary sedimentary beds may exist beneath its volcanic rocks, filling an original lake-depression in the old surface. In addition to the silicified plant-bearing beds just referred to, fragments of gray, sandy shale of Tertiary age, have been found in the valley of Dropping-water Creek, and it is not impossible that deposits of coal may exist there. This can, however, be tested only by means of boring operations, and if at any time such a test should be applied, the most promising locality seems to be that about two miles above the road-crossing of the creek.

Age of plant-bearing beds.

The stratigraphical position of the plant-bearing beds at this place is uncertain, the fossils being too few to determine this, and no other definite evidence being available. It is probable, however, that they are on or near the horizon of the Tranquille beds.

* Trans. Royal Soc. Can., vol. VII., sec. IV., p. 75. The specimens are those there described as coming from the vicinity of Stump Lake.

The area of Tertiary rocks shown at the edge of the map, to the east of Napier Lake, appears to consist entirely of basalts.

Near Trapp Lake, where massive dioritic rocks are immediately overlain by those of the Tertiary volcanic series, the former are frequently decomposed and soft, the felspar being more or less completely kaolinized and the hornblende replaced by chloritic or talcose minerals. On the east side of Napier Lake, the Nicola rocks immediately below those of the Tertiary, are decomposed and reddened, and often highly charged with iron pyrites; while at the north-east angle of Stump Lake, the older diabases are very much shattered and dolomitized. At the last-mentioned place, the alteration produced in the appearance of the older rocks is so considerable that the line between these and the Tertiary volcanic rocks was drawn with some difficulty, and it is probable that small areas of dolomitized sandstones like those previously described on the Nicola Valley (p. 195 B), may here, though in a more or less comminuted state, still rest upon the old broken surface. This dolomitization of the lowest beds of the Tertiary has been noted in several places where these rest directly upon the old surface.

Rocks immediately below the Tertiary.

To the north of Trout Lake, another small area of basalt was found. This forms escarpments toward Trout Lake and also on the hills to the south of Stake Lake. It is believed to be entirely separated by erosion from the larger basaltic area to the eastward, but this is not quite certain.

Near Trout Lake.

To the south west of Trout Lake, at an elevation somewhat greater than the last, a small patch of black basalt, containing some granitic fragments and showing flow-structure, was found by Mr. McEvoy.

In the upper part of the Meadow Creek valley, about midway between Trout Lake and Greenstone Creek, hard, white, gritty, calcareous clays are seen in several places, which may possibly be of pre-glacial age, and if so would be referable to some late stage of the Tertiary. These clays must in any case be of small thickness and cannot continuously occupy any considerable area. It is presumed that they are in reality a post-glacial lake deposit, and no attempt has been made to indicate them on the map.

Meadow Creek clays.

Tertiary Rocks on the Upper Part of Guichon Creek and thence to Ashcroft.

The northern edge of the principal area of Tertiary rocks here referred to, of which Savona Mountain is a part, has already been noticed in connection with the sections near Kamloops Lake (p. 172 B).

Upper Guichon Creek.

The outline of the south-eastern part of this area, as shown on the map, must be considered as an approximate one, for the whole of this country is so heavily covered with drift deposits that outcrops are seldom found. The outline given to the Tertiary volcanic rocks is thus largely based on the contour of the surface, taken in connection with the distribution and abundance of large blocks and boulders of these rocks. The exact point at which the line crosses Guichon Creek here, is, however, particularly indeterminate.

Tuffaceous
strata.

On the upper part of Guichon Creek, west of Toon-kwa Lake, low exposures were found of soft tuffaceous rocks, whitish and yellowish, resembling those described on the Deadman River (p. 221 B). These are supposed to underlie the basalts which elsewhere appear to characterize the whole tract drained by the northern sources of Guichon Creek, and are often extremely abundant in the form of loose masses and boulders. These generally present nothing unusual in their appearance, but are of brownish or gray colour, and not infrequently vesicular. The southern extremity of these rocks, north of the mouth of Meadow Creek, consists of olivine-basalt. Further south, to the east of the upper end of Mamit Lake, while the rocks actually seen appear to belong to the Nicola formation, some specimens of a material rich in fresh olivine and much resembling a Tertiary rock, have been collected. It is, therefore, possible that a Tertiary outlier may occur near here, and in fact, not improbable that several small patches of Tertiary volcanic rocks may yet be proved to exist in the country to the north-eastward of Mamit Lake and between the lake and the south side of Meadow Creek. The volcanic rocks of the Nicola formation are themselves here so little altered, that in hand specimens it is not always possible to distinguish them from those of the Tertiary.

Meadow
Creek and
Mamit Lake.

To the west of Mamit Lake, a small patch of Tertiary volcanic rock was found by Mr. Amos Bowman. It forms a perfectly flat little elevation, the limits of which have been fixed by distant views and bearings only.

Conglomerate
boulders.

It may be added, that the occurrence of loose pieces of conglomerate resembling that of the Coldwater series, in the valley of Guichon Creek above the mouth of Meadow Creek, suggests the possible existence of outcrops of this character to the north-westward, in the drainage-basin of the stream. It may well be, however, that these have been carried southward during the glacial period from the conglomerate area to the west of Savona Mountain, or even from that of the vicinity of Copper Creek.

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Forge Mountain and the hills attaching to it on the west, are chiefly capped by basaltic rocks, nearly horizontal, but varying slightly in the level of their base from place to place. Toward Mount Glossy, the base-level of the basalts rises very considerably. The summit of Forge Mountain itself, was found by Mr. McEvoy to be largely, perhaps entirely, composed of a gray glassy basalt, containing fragments of granite and other older rocks. Cinder Hill is capped by basalts and basalt-breccias.

The volcanic rocks on and about Mount Glossy, are chiefly brown and gray basalts, often vesicular and occasionally brecciated. Between Mount Glossy and Barnes Creek, the rocks met with are somewhat more varied, comprising basalts, red porous eruptives without macroscopic characters and gray tuffs. On the north side of Barnes Creek, similar materials are found, with the addition in one place of a pikrite-porphyrity,* and at the base of the section of a small thickness (observed by Mr. McEvoy) of soft basaltic tuff.

The detached area of Tertiary volcanic rocks that overlies the Cretaceous to the west of Barnes Lake, near Ashcroft, is a peculiar mass of mica-porphyrity, very homogeneous in its general character, but varying a little in appearance and hardness from place to place. It forms a rather prominent low hill on the side of the wide valley, and, as viewed from a distance, shows an appearance of massive bedding parallel to the general slope of the hill, indicating the existence of a pre-Tertiary depression near that now occupied by the river. That this rock here represents an outlier of a once more extensive flow, is shown by the fact that, a couple of miles further south, a narrow selva of the same material† is found on the hillside, resting upon the



FIG. 8. TERTIARY OUTLIER SOUTH-EAST OF BLACK CAÑON.

a. Cretaceous. b. Mica-porphyrity. c. Basaltic flow, separated from the last by a period of denudation.

sloping and denuded edges of the Cretaceous rocks and capped by a horizontal bed of columnar basalt. The mica-porphyrity is here

* Appendix I, No. 65. † Appendix I, No. 44.

affected by a well marked flow-structure on a small scale, parallel to the inclined surface upon which it lies, and its upper surface has been levelled off by denudation between the time of its eruption and that of the basalt. Another small occurrence of the same rock, was found at the south edge of the Cretaceous, about a mile back from the river, but this is in all probability merely a dyke.

PLUTONIC ROCKS.

Granitic
rocks of Coast
Ranges.

The granitic rocks of the Coast Ranges, to the west of the Fraser, may be characterized briefly as a group, and require no detailed notice. They consist almost exclusively of gray granites of medium coarseness of grain, passing, in their composition, from biotite-granite through biotite-hornblende-granite, to forms in which hornblende preponderates, and which may be named hornblende-biotite-granites. The biotite-granites are the most abundant, and those in which hornblende is largely represented are not found to characterize large areas.

Their charac-
ter.

Many local variations in texture are of course found, but on the whole, these granites are very uniform in character. They seldom weather rusty, while the schistose rocks associated with them almost always do so, and thus the massive granites are pretty easily distinguished, even at a considerable distance. The outlines given to the granitic areas in the Coast Ranges, depend largely on such definition, resulting from examinations and sketches made from the several high points which were ascended. The actual forms of the mountains are often largely dependent on the nature and direction of the jointage planes, by which the granites are affected in an unequal degree in various places. About Kl-ow-a Mountain, the jointage was noted to be particularly bold. Pegmatite veins also abound in some localities, and in other places the granites are found to be cut by numerous dykes, of which the more characteristic appear to be divisible into two classes, viz., gray dykes consisting of quartz-mica-porphyrity or of mica-porphyrity and dark brownish or black, basic dykes.* Dykes of the last-named character, were observed in places near to the summit of Stein Mountain, to have assumed a foliated character as a result of subsequent pressure, becoming amphibolites. Both classes of dykes also cut the schistose rocks associated with the granites.

Dykes.

Foliated gran-
ites.

The granitic rocks are frequently more or less foliated in their structure, passing into forms which may be called imperfect gneisses, but every gradation is found, in some places, between these and the massive

*Appendix I., Nos. 93, 94, 95.

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granites, from which they appear in most cases to have been produced by pressure. Such rocks are most abundant, as a rule, near the contact of the granites with the distinctly bedded Palæozoic strata, which in some places occur as isolated infolds in the granites; and it is probable in other cases where well foliated granites are met with, that the upper part of a compressed syncline, which has originally included Palæozoic rocks, has since been removed by denudation.

It is not always possible, however, to separate the highly altered bedded rocks, where these have passed into crystalline schists, from the associated materials which are believed to represent foliated granites. In these cases a separate colour appears on the map, but this must be understood to indicate merely such doubtful rocks, and not to represent a separate formation. It will also be understood, that the outlines of these gneissic or foliated bands are necessarily indeterminate, and that in many cases the distinctive colour is employed rather to indicate the existence of such rocks than to define their actual extent. These remarks apply to the Botanic, Scarped and Lytton Mountains as well as to those of the Coast Ranges.

Associated
metamorphic
rocks.

An examination of some limited areas, might easily lead to the belief that schistose and foliated rocks of the kind above described, constituted representatives of an Archæan series, and it is of course possible that remnants of such a series may exist here; but there is, in my opinion, no sufficient evidences for such a conclusion in this particular region. In the Shuswap series of the Selkirk and Gold ranges, the circumstances are different, for there, rocks similarly crystalline in character are found unconformably beneath Cambrian strata and are interbedded with limestones and quartzites.

Probably not
Archæan
rocks.

The following notes on rocks of the character above referred to, in the Coast Ranges, may be added here :—

Near Kl-ow-a Mountain, and just beyond the southern edge of the map, a narrow zone of blackish and gray micaceous-schist was found, and there may be more than one of the same kind in this vicinity. That examined was scarcely more than quarter of a mile in width. These rocks have somewhat the aspect of highly altered argillites. The high ridge which separates Stein Mountain from the Fraser Valley, is largely composed of rocks showing more or less gneissic structure. Most of these are pretty evidently foliated granites, but there are also some fine-grained micaceous schists, which may be of different origin.

Near Kl-ow-a
Mountain.

Stein Mountain

Two small areas crossed by Mr. McEvoy on Si-whé Creek, consist chiefly of finely laminated, fine-grained, greenish actinolite-schist, and

Si-whé Creek.

of dark-gray micaceous schist, all much twisted and intersected by granite dykes. Parts at least of these rocks probably represent materials originally bedded.

Lytton
Mountains.

The Lytton Mountains, with the southern part of the Scarped Mountains and Botanie Mountain, are separated from the Coast Ranges by a narrow belt only of stratified rocks. The crystalline rocks of these mountains may therefore be considered as practically connecting with those of the Coast Ranges.

Lytton Mountains, consist chiefly of greenish-gray and pale-gray granite, generally hornblende-biotite-granite, in which, in many places, the hornblende much preponderates. These rocks are cut by numerous jointage planes, which give rise, in the rather flat upper levels of the mountains, to roughly hummocky forms. Near the south line of the map, most of the granites appear to weather easily, and in some places produce yellowish rubbly slopes of débris. Along the Thompson, on the north base of these mountains, numerous veins of pegmatite cut the granites. Most of the granites are here quite massive, but several narrow belts or tongues of gneissic rocks, with gray or green hornblendic or micaceous schists were noticed. In the eastern part of the mountains, these run in bearings nearly east-and-west, but toward the Fraser River, they assume the more usual north-north-westerly trend. Some of these almost certainly represent much-altered stratified rocks. They are always greatly shattered and weather to rusty colours.

Scarped
Mountains.

On the opposite or north side of the Thompson, in the southern part of the Scarped Mountains, the greatest development of gneissic rocks, and that which most closely resembles some part of an ancient crystalline-schist formation, occurs. The bedding appears to be very regular upon the large scale, the dips being northerly at moderate angles, and a very considerable thickness of such rocks is shown in the bare slopes and cliffs which face toward the river. Numerous dykes, many of them doubtless of Tertiary age, run across the face of the cliffs. The rocks themselves include hornblendic and biotitic gneisses, quartz-mica-schists, etc.

Pegmatite
veins.

On the west of these exposures, near the mouth of Botanie Creek, is a remarkably sharp crest or ridge, composed of granitic rocks, and cut in all directions by a network of pink pegmatite veins, like those noted in the northern base of the Lytton Mountains. These are particularly well shown on the vertical western face of the little ridge.

Near Lytton.

Between the mouth of Botanie Creek and the bank of the Fraser, immediately north of Lytton, the rocks are all gray granite, much de-

composed and somewhat foliated by pressure, with the development of secondary mica.

The Botanie Mountain mass, separating the stream of the same name from the Fraser, wherever examined, on its eastern and western slopes and along its crest, appears to consist almost entirely of dark greenish and blackish dioritic rocks, including quartz-diorites, but sometimes very rich in hornblende. These are generally rather fine-grained, but occasionally coarse and medium-grained, and somewhat resemble the hornblendic granites of Lytton Mountains, though here decidedly more basic in composition. Gray granites of the ordinary type, were also seen near the south-eastern edge of the ridge, on the Fraser Valley, and at its northern end, but sparingly. Numerous narrow bands of bedded or foliated rocks also occur throughout, their general strike being parallel to that of the run of the ridge, but their dimensions are so small that it would be impracticable to represent them upon a map of the scale of the present, even if it should be proved possible to define them with accuracy.

Similar dark diorites and mica-diorites, were found on the lower part of La-loo-wissin Creek, where it cuts across the line of the Botanie Mountain ridge, and these become coarser grained and assume a granitic aspect, on approaching the mouth of the creek on the Fraser. To the north of La-loo-wissin Creek, along the east side of the Fraser Valley, rocks of apparently identical character prevail, till eventually concealed by the Tertiary volcanic beds near the mouth of the Three-lake Valley. Along this part of the Fraser Valley, these rocks are all very much decomposed and shattered, an effect elsewhere explained as being due to their proximity to the main line of the Tertiary volcanic eruptions (pp. 201 B, 204 B). They weather down readily into bare rubbly slopes of débris, producing forms which resemble those of the "bad land" hills in parts of the Great Plains.

On the west side of Fountain Ridge, near the Fraser River, the Cretaceous rocks are cut by a couple of granitic masses of relatively small size, and perhaps to be regarded as representing merely large dykes of granite. These are medium-grained granites of speckled black and white aspect, and on microscopical examination by Mr. Ferrier, prove to be hornblende-granites and biotite-hornblende-granites.* Similar intrusions in the Cretaceous were found on the west side of the Fraser between Lillooet and the mouth of Bridge River, and some miles up Bridge River. Many more of the same kind might doubtless be discovered by detailed search, but these are sufficient to show

* Appendix I., Nos. 91, 92.

that some at least of the granites of the region date from a period later than that of the deposition of the Cretaceous rocks.

Eleven-mile
Creek to
Pavilion
Creek.

The area of plutonic rocks represented as extending from Eleven-mile Creek to Pavilion Creek on the east side of the Fraser, has been examined chiefly in its northern part, the outlines given to its southern extremity being more doubtful. It consists almost entirely of dark-greenish, often markedly coarse diorite, which may in part become a hornblende-granite. This rock is not only jointed but is also much shattered, and presents none of the appearance of a granitoid eruptive as seen from a distance. It decomposes readily in some places, and is cut by numerous dykes referable to the Tertiary volcanic period. The most notable point about this occurrence is, however, the manner in which the diorite is here inextricably mixed with broken stratified diabase, a circumstance elsewhere described (p. 88 B).

Near Leon
Creek.

Further up the Fraser Valley, between Kelley and Leon creeks, another small granitic mass occurs, of which the relations to the adjacent bedded rocks are similar to those of the last, and are also elsewhere noticed (p. 93 B). This is more distinctly a granite than the last, but contains a good deal of hornblende.

West end
Marble
Cañon.

The granitic area found at the west end of Marble Cañon, consists of homogeneous gray granite of the usual type, generally micaceous, but sometimes with a certain proportion of hornblende. It differs much in appearance from the adjacent dark dioritic eruptive, above described as occurring on the lower part of Pavilion Creek.

Chi-poo-in
Mountain.

The granite of the Mount Martley and Chi-poo-in Mountain area resembles that of Marble Cañon. It is gray, medium grained and generally very homogeneous; usually a biotite-hornblende-granite, but passing into a biotite-granite. About the somewhat plateau-like summit of Chi-poo-in Mountain, the granite* is cut by several series of jointage planes in such a manner as to cause it to break out in slab-shaped pieces. These are weathered in places into rounded forms and resemble piles of loose boulders, though practically undisturbed.

Granitic area
between
Nicola and
Guichon
Creek.

The largest area of granitoid rocks contained in the Kamloops map-sheet, is that which constitutes the wide region of broken plateau lying between the Nicola Valley and Guichon Creek. This area is almost entirely characterized by hornblende-biotite-granites passing into mica-diorites in many places. No specimens of true biotite-granite occur among those brought back, and wherever the character of the rock was noted in the field, it is described as being more or less hornblendic; but

* Appendix I., No. 85.

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it is of course possible that such granite may be found in parts of this extensive tract which have so far merely been seen from a distance.

The western part of the area, for a width of from three to five miles along that margin, is principally composed of homogeneous greenish diorites and quartz-mica-diorites of granitoid aspect, but sometimes very rich in hornblende.* These occur about Wood's Creek, on the lower parts of Pu-kaist' and In-ki-kuh' creeks, to the west of Spaist Mountain and in the southern extremity of the area in the Promontory Hills. In Wood's Creek, pebbles of magnetite are found, which probably come from veins in the adjacent diorite, here somewhat epidotic and decomposed. Dioritic character of western border.
Magnetite.

No distinct line is found between the rocks just spoken of and the gray hornblende-biotite-granites which constitute the greater part of the area, including apparently nearly all of its western portion. On the upper part of the In-ki-kuh' Valley and about the head of Skuh'-un Creek, the rocks of this class hold both a pink and a white felspar. The granite of Spaist Mountain was observed to be unusually shattered, containing many veins of epidote and quartz, with pegmatite veins and dykes of fine-grained granite. Some contact phenomena, seen along the eastern edge of the granite mass on Guichon Creek, are elsewhere referred to (p. 144 B). Western part.
Contact phenomena.

The general plateau-like form of this granitic region, is well seen from high points, such as Spaist Mountain, but at the same time its rough, hummocky and broken character in detail is very apparent. Considerable areas of bare whitish granite may be observed over all parts of the area. About the head of Skuh'-un Creek, and to the eastward for some miles, the surface of the plateau was found to be composed largely of broken angular or partially rounded granite blocks, probably due to the action of the frost and weather since the glacial period, as the granite is here very much jointed. General appearance of plateau.

The northern part of this great tract, is largely concealed by Tertiary volcanic rocks, but where it can be followed, to the west of Mount Glossy and near the lower part of Barnes Creek, gray granitoid diorites, similar to those found elsewhere in the western portion of the area, prevail. Due west of Mount Glossy and near the edge of the Nicola rocks there, dark gabbro-like diorite was found in some places, and on the east side of Barnes Lake a rock determined as a granite-porphry, occurs.† Further north, this eruptive mass occupies a considerable area on both sides of the Thompson, of which the northern extremity is cut by the Near Barnes Creek

* Appendix I., Nos. 80, 81.

† Appendix I., No. 83.

section described on page 118 B, where some notes on its general character and relations have been given. It will suffice here to add, that the western part of this mass, near its contact with the Nicola rocks, is often a porphyritic diabase or gabbro,* while its eastern part is usually a dark mica-diorite. On the south side of the river, in some places, it again tends to become a granite-porphry and is often inextricably mixed with large masses of rocks of the Nicola formation, highly altered.

Near Eight-mile Creek.

Near Eight-mile Creek, what is probably an extension of the same plutonic mass, appears from beneath the Miocene volcanic rocks as a gray diorite, still holding a little mica. A third projection, bordered on both sides by rocks of the Nicola formation, is again formed chiefly of gray diorite, considerably decomposed in places, with some red granite on its north-eastern edge. The latter may be of newer or older date than the general mass, which is probably connected at no great depth with the main granitic area to the southward. (See p. 118 B.)

South of Penny station.

To the south of Penny station, another small patch, surrounded on all sides by volcanic rocks, appears to consist chiefly of rather fine-grained, pale-gray diorite, though specimens of a diabase similar in appearance, were also collected here by Mr. McEvoy. Also in connection with this great granitoid area, may be mentioned a small occurrence of blackish and greenish diorite, sometimes containing quartz, found on the east side of Guichon Valley. This runs southward, beyond the edge of the map, nearly to the Nicola River. It closely resembles the rock of the adjacent Promontory Hills, on the opposite side of the Guichon Valley.

Bonaparte Lake.

In the vicinity of Bonaparte Lake, a large area of granitic rocks appears where the volcanic Tertiary rocks have been removed by denudation. The entire coast of the lake, with most of its adjacent hills, and particularly the range named as the Rim Hills, to the north of the lake, may in fact be described as granitic. The rocks are so similar to many of those already noticed, that they scarcely require more than mention. They consist chiefly of gray or sometimes pinkish hornblende-biotite-granites, hornblende-granites and diorites of granitoid aspect; the last-named being probably the least common rock. To the westward, rocks of the same character continue in the eroded valley of the Bonaparte to about the confluence of the North Branch, where they are represented by a somewhat peculiar syenite, containing some augite and of a pinkish colour.†

North Branch of Bonaparte.

* Appendix I., No. 84.

† Appendix I., No. 90.

A southern spur of the same granitic area, which reaches Granite Lake, consists of hornblendic granites similar to those of Bonaparte Lake. At Granite Lake, these are gray in colour, and are traversed by pegmatite veins and contain masses of greenstone and of green schistose rocks, with which they appear to form a contact in this vicinity.

Near Uren's, further west on the Deadman River, the plutonic rocks seen are probably an extension of the same mass, though now isolated by drift, rendering their outline uncertain, but appear to be chiefly dark, highly hornblendic diorites. Another branch of the Bonaparte Lake area runs toward Skoatl Point. This likewise consists of gray granites, probably in the main hornblendic, though much covered by drift deposits and therefore seen only in occasional isolated exposures.

At Tsin-tsoon'-ko Lake, a small area of gray biotite-hornblende-granite occurs. Tsin-tsoon'-ko Lake.

The area of granitic rocks indicated on the map to the east of Bonaparte Lake and near the North Thompson River, has been very imperfectly defined. It occupies a rough, broken and wooded country, but so far as seen, appears to consist of rather hornblendic gray and greenish-gray granites, with some diorites. Granitic areas near North Thompson.

The definition of the next small area of granite to the southward, that to the west of the North Thompson and south of Skull Creek, is equally imperfect, its western limit not being properly ascertained. Where seen, it consists of gray hornblende-biotite-granite of rather fine grain.

Continuing to the southward, a considerable area of granitic rocks is found on the east side of the North Thompson near Sullivan Creek. The characters of these are rather peculiar, but they show a decided resemblance in texture to those of the Edwards Creek and Jamieson Creek intrusions of the same vicinity. The granite is generally pinkish-gray, and when the bisilicates are not entirely decomposed, hornblende is the preponderant one. The felspar crystals are rather large and somewhat porphyritic, and the stratified rocks near the granite, show, both here and in the other cases mentioned, very considerable alteration.

The Jamieson Creek granite mass may extend further to the northward than shown on the map, as its limit was not defined in that direction. It is of fine or medium grain and either gray or pinkish in colour, the latter tint being apparently due to the oxidation of iron pyrites contained in it. It is everywhere considerably decomposed, the bisilicates being scarcely recognizable, and is traversed by many small

and some large quartz veins. The latter continue into the adjacent hardened and slightly micaceous argillites, and are those which have been located as mining claims (p. 336 B). To the south of Jamieson Creek, the granite runs out in dykes among the schistose argillites. It is evidently the occurrence of the granite as an intrusion in the stratified rocks at this place, that has resulted in the production of the auriferous veins of the locality, and its extent and character thus assume a certain degree of economic importance.

Auriferous veins.

Near Edwards Creek.

Near Edwards Creek, another plutonic mass enters the area of the map from the east. This is a gray, to pinkish-gray, rather coarse-grained rock, much jointed, with numerous blade-like and twinned felspar crystals, considerably decomposed, and often containing much iron-pyrites in scattered grains. It has been microscopically examined by Mr. Ferrier, who describes it as a somewhat porphyritic syenite.* Its eastern edge, in some places, where in contact with the surrounding rocks, becomes a diorite. Specimens of its pyritous and rusty portions subjected to assay, afforded traces of gold (p. 312 B). It evidently represents a truly intrusive rock, and the stratified materials in its vicinity are again found to be much altered.

Syenite carrying gold.

Three miles south of Edwards Creek, and also on the east side of the North Thompson, a small mass of greenish-gray diorite appears in the bottom of the valley, but the detrital deposits prevent its precise definition.

The peculiar and somewhat diversified mass of crystalline rocks which forms Battle and Cherry bluffs on Kamloops Lake, is elsewhere described in connection with the Tertiary volcanic rocks of the vicinity (p. 158 B) of which it is believed, at least in great part, to have constituted the vent. To the south-east of the Cherry Bluff exposures, after an interval of about three miles covered by Tertiary volcanic materials, rocks of the same kind are again found in the ridge named Coal Hill on the map. These are gabbros and dark diorites, containing some mica.† Further to the eastward, near Peterson Creek and Separation Lake, in the same area, these are replaced by fine-grained gray granitoid rocks, and it is possible that plutonic rocks of two distinct periods are here represented.

Coal Hill and vicinity.

In some places, the rocks of this area, which is about ten miles long in all, have suffered considerable local alteration and decomposition, resembling that which is seen to have affected the rocks of Cherry Bluff. At or near the west edge of these rocks, at their northern extremity, thin veins of magnetite were found by Mr. McEvoy.

Magnetite.

* Appendix I, No. 89.

† Annual Report, Geol. Surv. Can., Vol. V. (N.S.), p. 60 B.

On the edge of the mass overlooking Edith Lake, a very coarse diorite, containing magnetite in large crystals, was observed to occur.

About seven miles to the southward of Kamloops, the northern end of one of the largest granitic areas covered by the map is found. This area runs southward by Trout Lake and parallel to the direction of Moore Creek, to the north shore of Nicola Lake, with a total length of nearly thirty miles. It is identified throughout with a rather high and somewhat broken plateau country, and except where overlapped by Tertiary volcanic rocks near its northern end, is everywhere found to be surrounded by rocks of the Nicola series. The eastern edge has been pretty accurately determined, but much of its western outline must be regarded as approximately correct only, as shown on the map, this part of the region being in general not only thickly drift-covered, but also heavily wooded and difficult to explore.

Granite west
of Moore
Creek.

Wherever examined, the rocks of this large area appear to be very uniform and homogeneous in their character, consisting as a rule of gray biotite-hornblende-granite of medium grain, generally with a considerable, and sometimes with a rather large quantity of quartz. True biotite-granite also occurs, but no highly hornblende granites or diorites have been observed, except in the instance of a very coarse diorite, locally developed, near the west end of Trout Lake, but which may not have the same date or origin as the main granite mass.

Lithologically
uniform.

The granite is sometimes more or less distinctly foliated, for a narrow width near its contact with the stratified rocks, but this effect is quite evidently due merely to the conditions of contact, which are elsewhere referred to at greater length (p. 129 n). In this area, the granite was in several places found to weather easily and to become superficially decomposed. This tendency, when in connection with well marked jointing, gives rise to miniature tors, and to the production of great numbers of boulders which still remain nearly in place. Granite surfaces breaking up into such boulders, were particularly noted on the plateau between Moore Creek and the head of Clapper-ton Creek.

Contact
phenomena.

In the neighbourhood of the edges of the granite, the stratified rocks are frequently penetrated by quartz-veins, and it is highly probable that the metalliferous veins of the vicinity of Stump Lake, are connected in their origin with the production or intrusion of this neighbouring granite mass.

Development
of quartz
veins.

About Campbell Creek and Trapp Lake, another important granitic area is in part covered by the map. The granites composing this area are not dissimilar in appearance to those of the last, but are somewhat

Campbell
Creek and
Trapp Lake.

more hornblendic, being either hornblende-granites or hornblende-biotite-granites—in some cases possibly quartz-diorites.* The rocks generally, differ little over the whole area, but on the west side of Trapp Lake, near their contact with the stratified materials, are represented by a black-and-white diorite. The character of the contact of these granites with the rocks of the Nicola formation is noted on another page, as well as the fact that they include, to the east of Newman's, some much altered remnants of the diabases of that series (p. 123 B).

Near Douglas
Lake.

The granitic area to the north of Douglas Lake, is occupied by a nearly homogeneous mass of medium to somewhat coarse-grained gray granite, which is in some places characterized by a preponderance of hornblende, in others by that of mica. It was seen in several localities to be cut by conspicuous parallel jointage planes, in such a manner that it might easily be quarried in well chosen spots. The fine amphibolites and argillites which appear to surround this mass, are considerably altered and disturbed, and are traversed by numerous small quartz veins.

GLACIATION AND SURFACE DEPOSITS.

Importance
of surface
deposits.

The character and arrangement of the surface deposits which cover the older rocks in this district, as elsewhere in British Columbia, are to be explained chiefly by the events of the glacial period. It is thus important, even from a strictly practical point of view, that the nature of the changes brought about during this period should be understood. It is nevertheless the case that the history of this period, owing to the indeterminate character of much of the evidence relating to it, is as yet imperfectly known, and considerable diversity of opinion prevails as to the explanation of some portions of the evidence. While difficulties of this kind yet remain even in the little-diversified and closely studied eastern parts of North America, and in Europe, it is not surprising that they should also attend the history of the same period in British Columbia, where the varied and bold relief of the surface tends greatly to complicate the investigation. The researches carried out in this province have, however, already resulted in the discovery of some interesting facts, which are not only important locally but bear also upon the general questions of glaciation.

Economic
features.

The most obvious effects of the period of glaciation on the district here referred to, are those connected with the transport and distribution of *débris* or, 'drift,' which has gone to form the boulder-clay,

* Appendix I., No. 87.

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* Report
† Vol. V

has been left in the shape of moraines, or appears as the material of the numerous terraces which are everywhere so characteristic a feature of the country. "The great accumulations of loose material formed at this time are also responsible, though less directly, for changes in the drainage system of the country, by the blocking up of pre-glacial river-valleys, leading to the diversion of streams or the formation of lakes. From an economic point of view, the geology of the glacial period has some features of special interest. It has determined the character of the soil, and must also be taken into account in the investigation of the superficial deposits in which gold placers are worked." *

In a paper published some years since in the Transactions of the Royal Society of Canada,† on the Later Physiographical Geology of the Rocky Mountain region in Canada, with special reference to changes in Elevation and the History of the Glacial Period, I have endeavoured to give a comprehensive review of the events of the glacial period in British Columbia as a whole, and to connect these with those of the adjacent area of the Great Plains. This review was based upon the very numerous observations made by me in various parts of the whole region described, most of which are recorded in the reports of the Geological Survey. The method of treatment adopted in it is, however, intimately connected with certain hypotheses as to the course of events, some of which must be considered as still open to question, while all are held subject to modification in the light of new facts. In this Report, it is proposed to record the principal observed facts within the district covered by the map to which it relates, with as little reference as possible to the theoretical explanations which these may appear to warrant. To a certain extent, however, the sequence of events during the period of glaciation is so well proven, as to admit of the grouping of the observations under headings approximately in their order of occurrence.

To provide the reader with some scheme of events, with which the facts subsequently grouped by kind may be compared, a provisional outline of the glacial history of the Cordillera will in the first place be presented. Though at the time it was written this appeared to accord with all the observations collected during many years of work in the region, it may probably be already subject to modification in some particulars. Care will be taken to note the facts which appear to conflict with its tenor, although I am not yet in possession of a sufficient body of such facts to induce me to undertake a general revision of the scheme.

Previous
review of
glacial history
of British
Columbia.

Historical
scheme
suggested.

Subject to
revision.

* Report of Progress, Geol. Surv. Can., 1877-78, p. 133 B.

† Vol. VIII., 1890.

What follows on this subject, is quoted, with little alteration, from an article published in the *American Geologist*,* which was prepared by me as a summary of the longer paper first referred to.

Early maximum of glaciation.

It would appear, that that part of the Cordilleran region of the West included in Canada, was, during an early and most severe phase of the glacial period, buried beneath a great confluent mass of glacier ice. Evidence of the existence of a system of glacial scoring and striation due to the southern part of such a great glacier, was obtained at an early stage of the investigation of the southern portion of the Interior Plateau of the province. Several hypotheses at first presented themselves as likely to explain the existence of this general (as distinct from the obviously local) glaciation of the region, but these were gradually eliminated or modified at later dates, and the conclusion above stated was arrived at. In 1887, in the course of an exploration of the Yukon district, evidence was found of the north-westward extension of the same great ice-mass, and its limits were approximately ascertained in that direction also.

Cordilleran glacier defined.

Having thus discovered the area of this great glacier, it was proposed to name it the *Cordilleran Glacier*, in order to distinguish it from the second and still larger ice-cap, by which the north-eastern part of the continent was at about the same time more or less completely covered.†

Development on the Coast.

The Cordilleran glacier, as thus defined, had, when at its maximum development, a length of nearly 1200 miles. The main gathering-ground or *névé* of this ice-sheet, was contained approximately between the 55th and 59th parallels of north latitude, that part of the ice which flowed north-westward having a length beyond these limits of 350 miles, that which flowed in the opposite direction a length of about 600 miles. When at its greatest, a portion of its ice also passed off laterally by gaps transverse to the Coast Ranges, and filled the wide valley between Vancouver Island and the mainland. The ice there divided and flowed in opposite directions, as the subsidiary, but yet large, glaciers of Queen Charlotte Sound and the Strait of Georgia. Ice from the main *mer de glace* does not appear to have crossed the Rocky Mountain range proper, on the other side, although considerable local glaciers were at the same time developed on the north-eastward slopes of this range.

Thickness of the ice.

That portion of the Cordilleran glacier which moved south-eastward along the Interior Plateau of British Columbia, is now known, from

* September, 1890, p. 153.

† *Geol. Mag.*, August, 1888.

numerous observed instances of striation crossing high points, to have covered the summits of isolated mountains of 7000 feet and more in height; a circumstance which implies that the ice reached a general thickness of 2000 to 3000 feet above even the higher tracts of the plateau, while it must have attained a thickness of over 6000 feet above the main river-valleys and other principal depressions of the surface.

During the maximum of the Cordilleran glacier, it appears that the Cordillerian region stood at a level considerably higher than it now does, while an important part at least of the Great Plains was probably depressed to such an extent as to admit waters in connection with, and at the level of, those of the sea. The eventual retreat of the Cordilleran glacier was contemporaneous with, if not caused by, a subsidence of the mountain region.

Cordillera elevated.

Subsidence.

The first effect of the decay of the great glacier, may be supposed to have been the production of lakes upon its surface or within the central part of the southern portion of its area, in the relatively dry region of the Interior Plateau. Along the borders of one or more such englacial lakes, terraces, composed of material resembling boulder-clay, were formed on projecting highlands.* The best marked and highest terrace to which this origin is attributed, has an elevation of about 5290 feet above the present sea-level, and this terrace (or others at or about this level) has now been recognized in a number of places.† Such 'englacial' lakes may have continued to increase in size, and to become lower in level, for some time, while a general subsidence also progressed. There is further, some evidence to show that, after the final draining of these lakes and as the great glacier retreated from the Interior Plateau, it was followed by gradually deepening water which was in communication with that of the sea. The boulder-clay deposit of the Interior Plateau is believed to have been formed principally during this retreat, at, or in water contiguous to, the retiring ice-front. The lower boulder-clay of the littoral was laid down under similar circumstances, but at a somewhat earlier stage in the glacial decadence, and as the submergence became deeper, stratified interglacial silts were formed above it in the same region.

Decay of great ice-sheet.

Following submergence.

The next change is supposed to have been a re-elevation of the Cordillera, during which most of the higher terraces of British Columbia were formed. Some further evidence of this rise is afforded by the removal at about this time of much of the previously formed boulder-

Re-elevation and second maximum of glaciation.

* These must at the time have resembled the *nunataks* of Greenland.

† See, however, in this connection, p. 249 B and foot note to p. 282 B.

clay from some of the larger river-valleys.* The land probably stood as high as (and possibly higher than) it now does relatively to the Pacific, and in consequence of its elevation and the severe general conditions of the climate of the period, it became again covered to a considerable extent by glaciers, which, however, were as a rule, of a local character and in evident relation to the various mountain ranges.

Second subsidence and period of stability.

Following the maximum of this second period of glaciation, came apparently a second subsidence, less in amount than the first, but sufficient to depress the Cordilleran region generally, to a level about 2500 feet below that which it holds at the present day. At this stage, and while glaciers of considerable size still occupied the mountain-valleys, and the position of the *névé* of the former Cordilleran glacier was probably held by an ice-cap of some size, the land remained nearly stationary for a long interval, and remarkable and important silt deposits, well bedded and of considerable thickness, were tranquilly laid down in different low tracts scattered along the Cordilleran region for a length of some 1200 miles. These deposits, the writer has in previous publications referred to as the *White Silts*, and as observations accumulated, it at length became evident that these silts possess more than a local significance. They appear, in fact, to constitute a well marked formation, characterizing a definite and long maintained stage of stability in the glacial history. In the various more or less completely separated basins in which they occur, their level is so nearly identical, as apparently to show that this must be referred to a common cause, which it is believed, in consideration of all the circumstances, and particularly in view of the vast area which the observations here referred to cover, can have been no other than the level of the sea at the time. No morainic or other accumulations have been found, such as to account for the production of lakes, in which these silts might be supposed to have been deposited, and had they been formed in separate lakes, held in either in the manner suggested or by glacier-dams, they would, in a region of such bold relief as the Cordillera, be expected to occur at very different levels in each basin.

Final retreat of glaciers.

The evidently somewhat rapid retreat of the already reduced glaciers of the second period, was apparently not in relation to subsidence of the Cordillera, but, on the contrary, seems to have been contemporaneous with, or was soon followed by, a progressive movement in elevation. It is supposed that this final decay of glaciers occurred chiefly in connection with a general amelioration of climate, by which the close of the

* The date assigned to this removal, depends on the existence and relations of the silt deposits next alluded to, in the same valleys.

glacial period as a whole was brought about, as to the cause of which no opinion is here offered.*

It is worthy of note, that most of the long fiord-like lakes of the mountain regions of British Columbia, can be shown to occupy portions of the abandoned beds of the glaciers of the stage of the White Silt formation. To the elevation which began about the time at which we have now arrived, the draining of the White Silt water, together with the formation of all the lower-level terraces, is supposed to be due. There appears, however, to have been one well marked pause, during which the littoral, at least, was at a height about 200 feet lower than it now is, and there is in addition some evidence of a succeeding movement in elevation of several hundred feet, which, if it occurred, constitutes the last important change of the kind in the region.†

Latest movements of land.

STRIATION AND SCORING OF ROCK-SURFACES.

The direction of motion and thickness of the ice-mass of the Cordilleran glacier, have been determined chiefly on the evidence of glaciated rock-surfaces met with at considerable elevations, such as the projecting points of mountains or the higher parts of the Interior Plateau itself. The more important observations of this kind have been detailed in the paper already referred to, but some additional observations of the same nature have since been made, while others, which did not appear to require mention there but are important locally, were not included in it. It may be well, therefore, in the first place to give a summary list of the principal observed localities of glaciated rock-surfaces in the district included by the map, with the direction indicated by each and its height above the sea. In the following list the localities already published are those included in parenthesis. In the paper from which these are here quoted, the latitude and longitude of each observation-point was recorded, but, because of the map now printed, upon which the observations are plainly indicated, it is no longer necessary, in the cases here mentioned, to resort to this indirect method

Direction of observed striation.

* Two principal periods of glaciation are here postulated, because evidence of more than two has not been obtained in any particular region in the Cordillera. It is, however, by no means certain that the two boulder-clays of the Strait of Georgia and the two boulder-clays of the Cariboo region (Annual Report, Geol. Survey, vol. VII., p. 24 A) correspond, the latter being high up, and far in towards the central *névé* region. The possibility of several great oscillations in temperature is by no means excluded by the facts so far ascertained.

† Cf. Canadian Naturalist, February, 1878.

of placing them. The directions of striation stated are in all instances true bearings:—

Above 3000
feet.

(1). GLACIATION NOTED AT LEVELS ABOVE 3000 FEET.

LOCALITY.	Height above sea, in feet.	Direction.
<i>Plateau between North Thompson River and Deadman River.</i>		
South of Bonaparte Lake.....	4840	S. 35° E.
(Skoatl Point).....	5840	S. 37° E.
2 miles E. of Young Lake.....	4170	S. 19° E.
(6 miles N. E. of Deadman Lake).....	4220	S. 30° E.
(8 miles westward from Tsai-tsoon-ko Lake).....	5220	S. 34° E.
Poison Hill.....	5370	S. 41° E.
1 mile E. of Caribou Lake.....	5810	S. 48° E.
(Basalt Point).....	5840	S. 35° E.
Near Porcupine Ridge.....	5920	S. 39° E.
3½ miles south of Tranquille Lake.....	4830	S. 40° E.

*Plateau between Thompson and Nicola Valleys, and Valley which connects
Nicola Lake and Kamloops.*

6½ miles east of Ashcroft.....	3150	S. 55° E.
North part of Mount Glossy.....	5950	S. 40° E.
(Cinder Hill).....	5070	S. 50° E.
Between Pu-kaist and In-ki-kuh Creeks.....	4000	S. 13° E.
(Spaist Mountain).....	5780	S. 28° E.
Plateau S. W. of Spaist Mountain.....	5520	S. 27° E.
" " ".....	5550	S. 30° E.
" " ".....	5350	S. 28° E.
" " ".....	5200	S. 27° E.
Choo-whels Mountain.....	6000	S. 35° E.
(Plateau 14 miles S. of Kamloops).....	4190	S. 31° E.
Edge of high plateau 2 miles S.S.W. of Separation Lake ..	abt. 3500	S. 6° W. to S. 27° W.
3 miles N.W. of Head of Stump Lake.....	3550	S. 20° W.
Little Timbered Hills.....	4800	S. 15° E.
Between Clapperton and Guichen Creeks.....	4200	S. 35° E.

Douglas Plateau.

2 miles E. of Stump Lake.....	3500	S. 15° W.
½ mile N.E. of Glinpee Lake.....	abt. 3800	S. 9° W.
2½ miles east of last.....	4030	S. 18° E.

Other Localities.

Meander Hills.....	3240	S. 12° W.
(Nicocamen Plateau).....	5630	S. 13° E.
Lytton Mountains.....	abt. 6200	S. 23° W.
(Mount Murray).....	6880	S. 10° E.
Pass N.W. of Mount Murray.....	5480	abt. S. 20° E.
Trachyte Hills.....	5200	S. 51° E.
(Arrowstone Hills).....	5500	S. 35° E.
(Summit E. of Paul's Peak).....	3520	S. 51° E.

North Thompson
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(2). GLACIATION NOTED AT LEVELS BELOW 3000 FEET.

Below 3000
feet.

LOCALITY.	Direction.
North Thompson River above Indian Reservation.....	S. 2° E.
Inner Valley, near Edwards Creek.....	S. 13° E.
East side Stump Lake, north end.....	
Above and behind Battle Bluff, N. of Kamloops Lake.....	N. 85° W.
Hills south of Semlin Valley.....	S. 30° E.
2000 feet above Fraser River, W. side, 4 miles S. of Lytton.....	abt. S.

In explanation of the observations included in the above list, it may be stated, in the first place, that the small number of these referring to levels below 3000 feet as compared to those at greater elevations, affords no true index of the relative frequency with which glaciated rock-surfaces occur above and below this plane. If all the glaciated surfaces met with below 3000 feet had been duly entered, probably a hundred observations might have been recorded, but, as a rule, glaciation met with at such lower levels was not specially noted, being obviously so much affected by the bold relief of the country, and by the tendency of the ice to follow the main troughs in the directions of their lengths. At high elevations, on the contrary, glaciation was always sought for, and carefully noted when found, though the disintegration of the rock-surfaces is frequently such that no distinct striation, but only the general forms of the projecting parts, still remain. In the examples collected in the list, however, no merely general evidence of this kind is included. In nearly all the recorded instances of glaciation at high levels, the directions have also been obtained either from approximately flat surfaces, or from slopes at right angles to the general direction, as it is notable that on oblique slopes the direction always varies, to an indeterminate amount. Some of the recorded directions, however, even those obtained on points of very considerable height, were still obviously influenced by the vicinity of more elevated tracts or by that of important depressions. In such cases, a study of the local conditions nearly always shows that the ice was affected by a tendency to veer away from the elevations and to slant down towards the hollows. To determine all the local deflexions thus produced in a great mass of ice which moved across a broken country like this, would be an almost endless task, even if the instances of well-preserved glaciation were much more numerous than they are. In a general way, it may be stated that the ice appears to have moved in more or less complete parallelism with the larger valleys below the 3000-foot contour, follow-

Number of
observations
above and
below 3000
feet.Influence of
local features
on direction.Particularly
at lower
levels.

Differential motion.

ing their trend in the sense which agrees in each case most closely with that of the main direction of its motion. In this respect, these larger valleys appear to have acted, in imposing their direction on the mass, much as the rifling does on the bullet in a gun-barrel, but it is impossible to say to how great an extent what is known as 'stripping' in the illustration cited, has occurred. In other words, it is probable that even (and perhaps particularly) at the time at which the thickness of the Cordilleran Clacier was greatest, the lower parts of the mass followed the larger valleys, while the higher parts broke away from these and continued to pursue the general direction. It must further be remembered, that when the ice-sheet finally disappeared, its thinned and melting edge must have occupied each part of the district successively, and that at this time tongues or lobes of ice projected southward in some of the larger valleys, when the ice-covering on intervening areas of higher plateau had vanished or had at least broken up into detached masses, which had ceased to participate in the general movement. The existence of small terminal and lateral moraines, in evident connection with such tongues or lobes, is the chief apparent evidence of this, but it is mentioned here as tending still further to account for the movement of ice along the valleys, and for the purpose of introducing the remark that the striation then and in this way formed, is not clearly separable in all cases from that produced by such differential motion in the main mass as may be supposed to have occurred.

Average direction.

The mean direction of the general glaciation of the district included by the accompanying map, obtained from all the recorded observations at heights above 5000 feet (rejecting only the observation on Lytton Mountains which was taken on a sloping surface and was manifestly affected by the neighbouring great valley of the Fraser) is S. 33° E. If, however, several observations, with respect to which local circumstances were observed which explains their departure from the average, are discarded, a mean direction of S. 33.5° E is obtained, which is probably better, and may be accepted as an approximation as close as can be arrived at.

Correspondence with main trend of Interior Plateau.

In the paper which has already been several times referred to, the main direction of motion of the southern part of the Cordilleran glacier, is stated to have lain between S. 30° E. and S. 35° E., with which it will be seen the result of the present discussion, confined to the area of the Kamloops sheet, corresponds. A line drawn from the southern part of Stuart Lake, to Osoyoos Lake, along the centre of the Interior Plateau, and as nearly as possible parallel to its main direction, with a length of 450 miles, runs S. 35° E., and with this the value here locally



G. M. DAWSON.—Photo, Aug. 26, 1890.
 GLACIATED BASALTIC ROCK OF THE HIGH PLATEAU.
 Near Porcupine Ridge. Elevation 5,380 feet.

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arrived at may again be considered as practically identical. It is thus evident, that the relatively depressed, though often rough and irregular region, which has been named the Interior Plateau, bounded to the south-westward by the Coast Ranges and on the opposite side by the Rocky Mountains and Gold Ranges, has given direction to the movement of the whole southern part of the Cordilleran glacier.

Particular attention may be directed to the examples of glaciation met with on the higher parts of the Arrowstone Hills and the Sil-who'i-a-kun region, between the North Thompson and Deadman rivers, because of the fact that no considerable area of equal height occurs to the north-westward (the direction from which the glaciating agent moved), for a distance of 350 miles. The character of the glaciated surfaces found on these rather notably high tracts of the Interior Plateau, is such as to show that heavy glacier-ice passed completely and uninterruptedly over them in the general direction already indicated, thus proving its practical independence of even the broader features of the local topography. This is very strikingly evident when standing upon the north-western edge of the Porcupine Ridge, whence a nearly level horizon is seen to extend to the limit of vision in the direction from which the ice came, while to the eastward of this direction, irregular elevations bordering the north-eastern edge of the plateau begin gradually to rise. (See Plate VI.)

Independence
of local
elevations.

It is unnecessary to attempt to follow in detail, the various local conditions which have resulted in producing directions of glaciation divergent from the normal one. The circumstances are, however, in some cases sufficiently obvious, when the arrows by which the observed directions are indicated on the map are examined in connection with the contour-lines. On such an examination it will be found that, in descending from the higher levels, an ever increasing degree of irregularity and complication is met with. It may be noted, however, in particular, that the great parallel valleys of the Fraser and lower part of the Thompson with the intervening and also parallel valley of Hat Creek, have together had so considerable an effect on the overlying part of the glacier as to impress upon it a nearly due southward direction of motion, even where it crosses a point so elevated as that of Mount Murray. The important valley of the North Thompson, by means of the massive rib of ice which must have filled it, has also exerted an important directional effect.

Effect of
the greater
valleys.

It appears also to be brought out, by an examination of the region covered by the map, that when the occurrence of opposing highlands forced the ice to diverge from its general direction, the divergence,

Divergence
usually east-
ward.

other things being equal, usually occurred to the eastward rather than to the westward. From this it seems reasonable to conclude that, in this part of the Interior Plateau, the weight of ice superposed on the western side was greater than that on the eastern, the maximum accumulation occurring here in the vicinity of the Coast Ranges.

Abnormal
directions
near Kam-
loops Lake.

In that part of the Thompson Valley which extends nearly due eastward from the mouth of the Bonaparte, for about fifty-eight miles, and which includes Kamloops Lake, some rather remarkable instances of glaciation nearly parallel in direction to the valley have been noted. Glaciation of this kind is found on the vertical front of Battle Bluff, near the level of the water of the lake, and again in the upper valley immediately behind and above the bluff at a height of 1000 feet above this level. Similar glaciation was again noted, in several places, on the hills to the north of the valley, some miles east of the Kamloops sheet.

Probable
differential
movement.

It is by no means certain in what manner this aberrant glaciation was produced, but as the general direction of glaciation is south-easterly and those parts of the valley affected run some degrees to the south of east, it appears to be probable that a lower part of the glacier-ice was here actually forced to follow this valley in an easterly direction. This is supported by the fact of the general tendency of the ice to deflect eastward where interrupted, and by the circumstance that the continuous range of high-lands to the south of the valley, did not permit any very great mass of ice to discharge southward by the Guichon Creek hollow; also by the observation of the abnormally great easting of the striation found on the summit of the ridge near Paul's Peak, which appears to be explicable only on the hypothesis of the addition, to the main flow, of an underlying mass with eastward motion, derived from the valley of Kamloops Lake. Without some such unusual condition, the motion of the ice would, in fact, here be likely to show a more direct southerly course than usual, for the great valley running southward from Kamloops by Stump Lake, must have been one of the main discharges for this part of the plateau. The ice, in fact, followed this valley, in an almost due southerly direction, till the valley began to turn to the westward, when it gradually resumed its normal course, across the Douglas Plateau.

Direction
across the
Trachyte
Hills.

An analogous case is met with in the abnormal amount of easting found in the striae on the summit of the Trachyte Hills, where it would appear that a thick rib of ice moving along the Marble Cañon valley, exercised a directional influence on the main mass after its discharge from that valley.

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It is, at any rate, scarcely probable that the glaciation of the second period was sufficiently extensive to result in the protrusion of glacier-tongues either from the Coast or Gold ranges so far into the area of the Interior Plateau as the vicinity of Kamloops Lake.* Neither are there any physical features in this vicinity such as to suggest the possibility of a local accumulation of glacier-ice during the second period of glaciation, although it may be pointed out that one or other of these occurrences might afford us an explanation of the manner in which the deep valley occupied by Kamloops Lake has been kept relatively free from drift deposits, a problem otherwise somewhat difficult of solution.

Extent of
glaciers of
second period.

SURFACE DEPOSITS OR "DRIFT."

In previous reports, the surface deposits referable to the glacial period have been divided for purpose of description under the heads of *unmodified drift* and *modified drift*. Drift deposits of one class or the other practically constitute the entire mantle by which the subjacent rocky surface is covered, for I am unable, within the limits of the Kamloops sheet, to adduce a single indubitable instance of the existence of gravelly or other unconsolidated materials referable to a time antecedent to the glacial period, while the most recent superficial deposits, such as those of the deltas of streams, fans, and alluviums of river-valleys, or those marking the positions of small lakes and ponds, with rock-slides or "screes," are inconsiderable as compared with the drift deposits proper. By far the greater part of the area is covered by drift, as above defined, probably not more than one-fifth or one-sixth of the surface in all being free from such cover.

Unmodified
and modified
drift.

In classifying the materials of the drift under the above heads, some consideration of the manner of their origin is involved, and it may be that the mode in which the deposits of the two classes were formed was not so different in character as is generally supposed. Practically, the unmodified drift includes the boulder-clay, the modified drift deposits of various kinds which have obviously in large part been formed by the re-arrangement of the materials of the boulder-clay and are generally speaking more or less distinctly stratified. The boulder-clay constitutes the lower member of the drift deposits, and the modified drift, where both are found together, invariably overlies it. Within the area of the map-sheet, no evidence has been obtained of the existence

But one
boulder-clay
recognized
here.

*It may be explained here, that marks indicating the extent of the second glaciation in the Thompson and Nicola valleys appear on the map accompanying my paper on the Glaciation of British Columbia published in the Quarterly Journal of the Geological Society for 1878, but that the further and much more detailed examination of the country, now leads me to distrust the indications previously relied on in placing these marks.

of more than a single boulder-clay, though both in the littoral of British Columbia and in the Great Plains* two boulder-clays have been recognized, separated in each case by a well marked zone of stratified materials.



FIG. 9. SECTION ON BARNES CREEK.

- a. Stratified gravels, silts and sands.
b. Boulder-clay, obscurely stratified.
c. Silty deposit; local inwash of the valley.

Beds below
boulder-clay.

The only probable instance observed of gravels older than the boulder-clay, is in an interesting section on Barnes Creek, about four miles east of Ashcroft, at an approximate elevation of 2800 feet. Twenty-five feet of boulder-clay, containing some distinctly glaciated stones up to two or three feet in diameter, here overlies about twenty feet of well stratified gravels, silts and sands. The surface of the underlying beds appears to have been planed off to some extent. They are well compacted, and the gravels hold some stones six inches in diameter. The pebbles are often sub-angular, but none of them are striated. The conditions represented here may possibly be those just preceding the advance of the main ice-sheet.†

The Boulder-clay.

General character of
boulder-clay.

The boulder-clay found in this district, differs in no essential respect from that found elsewhere in the northern part of the continent, and though varying somewhat in character in different places, preserves its well known features throughout. It consists of a paste of hard sandy clay, usually containing a considerable amount of fine sandy or silty material, and throughout its stones and boulders are generally abundantly though irregularly distributed. In colour, it varies from light brown, buff or yellowish to bluish-gray, the last-named being usually that characteristic of fresh exposures cut down to some depth from the surface, or of those which have been otherwise protected from weathering and sub-aërial agencies. Some of the contained stones are

* Also now in the Cariboo district, as before noted.

† Notable instances of gravel deposits, Pliocene and perhaps newer, have since (1894) been found in the Cariboo country to the north. Similar occurrences should now be sought for elsewhere. Their natural exposures are, as a rule, and necessarily, obscure and small.

found to bear traces of glacier striation and polishing, and a few are occasionally faceted. It is notable, however, that such scored and scratched stones are often rather scarce, and that a large part of the stones are well rounded and appear to have been shaped by ordinary water action like other pebbles. Local differences in colour and composition of the boulder-clay, are here not so well marked, nor can they be so closely correlated with the varying nature of the underlying strata, as for instance in some parts of the Great Plains, where the strata, being softer, are more easily incorporated as a part of the boulder-clay. Neither is the boulder-clay of this district so plastic and truly clayey in character as that of the St. Lawrence Valley or many parts of the Great Plains, where the disintegration of limestones, or of soft clayey beds of Cretaceous age, have respectively supplied much of the material. The contained stones are often, perhaps usually, chiefly those of each particular vicinity; but with these there is always a considerable and often a large proportion of stones of varied origin. In most places, a considerable part of these travelled stones is found to be obviously derived from some rock-exposures to the north-north-westward, in the line of the general direction of glaciation. This is particularly apparent when large surfaces of granitic rocks occur to the north-west of any particular place, as rocks of this class seem here, as usual, to have been specially productive of boulders. A part of this effect, doubtless depends on the generally superior elevation of the granitic regions. There is, however, considerable evidence of cross-mingling of material. The results of this are least obvious in the higher parts of the plateau and most notable at somewhat lower elevations.

In the case of stones which can be clearly referred to their places of origin (as for instance granitic fragments on basaltic plateaux) an examination of all the notes made, shows that these have seldom or never been transported in large numbers for a distance greater than about ten miles, in the direction of the glaciation. In smaller numbers, however, they have in several cases been traced to a minimum distance of twenty or twenty-five miles in that direction.

The above remarks respecting the derivation of the stones and boulders of the drift, apply specially to those included in the boulder-clay itself or obviously derived from it. The stones found on the alluvial points to which drift has been traced, at heights greater than that which the boulder-clay is known to characterize, often show considerable diversity in character, and their origin cannot always certainly be traced. Again, in the lower and larger valleys, the material

Local differences

Derivation of contained stones.

Distance of transport.

of the drift, in consequence of the carrying power of the rivers, and possibly of other causes, is much more varied.

Main develop-
ment of
boulder-clay
between 5000
and 3000 feet.

Speaking of the whole district included by the Kamloops sheet, as a result of the pretty complete examination of all its parts, it is very noticeable that, while many considerable areas even of the plateau country rise above 5000 feet, the greatest development of the drift deposits is found below this level. It is further probable that, though considerable quantities of drift occur in the deep and wide valleys which traverse the region, it is by no means so uniformly spread in these, and its mass, area for area, is smaller than that met with on some parts of the plateau above. To this general statement there are numerous exceptions, and though (as subsequently noted) there is reason to believe that the upper line of the heavy drift deposits is a rather definite one, it is impossible to fix any lower line for them. All that can be affirmed with certainty, is that the greatest average thickness and most continuous and unbroken development of drift deposits, is met with on those parts of the plateau between 5000 and say 3000 feet, above the level of the sea. The aggregate area of the parts of the plateau between these limits, constitutes probably half the entire area of the plateau region embraced by the map.

Further
localization of
areas of heavy
drift.

It is further found, however, that the drift deposits are as a rule much thicker and more important over some considerable areas of the region than over others, while certain parts of the plateau and some of the mountainous tracts are notably free from such deposits, even at elevations where these are generally best developed. An attempt has been made to define these areas upon a map, by laying down all the observations bearing upon them in a graphic form. The result is too indefinite for precise delineation, but sufficient to enable the statement to be made that the following areas are as a rule notably drift-covered.—

1. Area composing the Green Timber, Bonaparte and Kuk-waus plateaux, with the northern part of the Arrowstone Hills.
2. Area including the upper valley of Hat Creek and adjacent hills.
3. Area including the whole drainage system of Guichon Creek and comprising the upper parts of Fu-kaist' and In-ki-kuh' creeks on the west, with the heads of Cherry Bluff Creek and Peterson Creek on the east.
4. Southern part of the Sil-who'i-a-kun Plateau, and part of the Tranquille Plateau east of Watching Creek.
5. Dome Hills and plateau about the upper part of Reservation Creek.
6. The Douglas Plateau.

Areas with
sunny drift.

Of districts which are, on the contrary, notably free from drift deposits, the following may be mentioned:—1. The Marble Mountains. 2. The greater portion of the Pavilion Mountains, particularly

their south-eastern part. 3. The Lytton Mountains. 4. The Coast Ranges to the west of the Fraser, so far as included in the map.

The remainder of the surface of the country may be regarded generally as intermediate in respect to the development of the drift deposits.

On the hypothesis already outlined, it may be supposed that when the supplies of ice of the Cordilleran glacier began to fail and it entered its period of decadence, it must in the first instance have lost its head and motion, and while thus in an inert state, by processes of decay, it was in some places removed or melted away sooner than in others, forming pools, and eventually large englacial lakes, toward which the remaining ice would naturally begin to trend and in which greater deposits of drift material might accumulate. Some of these remaining ice-masses appear to have clung to, and continued to descend from certain of the mountain ranges and higher plateaux, while in other cases the very massive accumulations of ice filling the larger valleys may have persisted, though in an inert condition, long after the thinner ice overlying the adjacent plateaux had disappeared.

Possible cause of differences noted.

Before proceeding further with the description of the drift deposits of the tracts below 5000 feet, it may be well to note what has been observed respecting the drift of the very highest points to which it has been traced. Without entering into this branch of the subject in great detail, it may be stated that small erratics of varied composition and origin, have been found over all the most elevated points to the east of the line of the Fraser River. The Clear Mountains, near the western side of the map, in a number of places comprised within about twelve miles measured on the length of the range, exceed 7000 feet in elevation, and the highest point, Cairn Mountain, has a height of 7650 feet. Small erratics, composed of rocks not seen in the vicinity, are found everywhere to the summits, though mixed with much angular material of local origin. On Tod Mountain, 7250 feet in height, situated twenty-four miles north-eastward of Kamloops and a short distance outside the eastern edge of the map, although no stones were met with on the actual summit which could be positively affirmed to be far-travelled, such were found at a short distance below the apex. On Za-kwaski Mountain, a few miles beyond the southern edge of the map, between the Nicolaen and Fraser, with an elevation of 6600 feet, a few granitic pebbles three or four inches in diameter, were found on the actual summit, which is composed of volcanic rocks. Again, on Porcupine Ridge, the culminating point of the high plateau to the north of the sources of the Tranquille, though the entire plateau is here composed of volcanic rocks, granitic boulders and pebbles were found in moderate abundance to the highest points at 6030 feet.

Erratics of the highest points.

Having cited these more remarkable instances, it will be unnecessary to explain in detail that similar travelled stones are strewn over all the less elevated culminating points of the plateau, and that in many cases well above 5000 feet, these are met with in great abundance and in boulders of two, three or more feet in diameter.

Earthy drift
at high levels.

On most of the points exceeding 6000 feet in elevation, the shattered rock of the locality itself is abundant in angular fragments, but besides this, and in addition to the sprinkling of erratics, there is generally a certain small quantity of earthy matter. This is usually sandy in texture, and though probably to some extent of local origin, is doubtless in part to be classed as drift material, although it presents none of the characters of a boulder-clay. The summits of the Clear Mountains were observed to be characterized by an unusually large quantity of such earthy material, but wherever hollows or light slopes upon which it could lodge and remain occur, it is never entirely wanting.

Absence of
erratics in
Coast Ranges.

In the eastern part of the Coast Ranges which comes within the limit of the Kamloops sheet, no instances of erratics at notable elevations were discovered, and generally speaking the quantity of incoherent material, apart from mere broken rock of local origin, is inconsiderable in all the higher parts of these mountains. This, I believe, to be probably due to the circumstance that the direction of flow of the ice, to which the transport of erratics generally must be attributed, was at all times from, rather than toward these ranges, and that they were probably among the last parts of the surface to be freed from an icy covering.

Terrace-like
forms of
boulder-clay
deposits.

What has been stated above, on the greatest development of the drift deposits as a whole between heights of about 5000 and 3000 feet, applies in a special sense to the main mass of the boulder-clay. It is the remarkable quantity of this material which is spread over those parts of the country between the elevations mentioned, that chiefly justifies the general statement. At these intermediate heights, or in other words over the whole of the less elevated parts of the plateau proper, the boulder-clay is found in its greatest development. Here it often forms the actual surface in which the trees are rooted and not infrequently spreads for miles with a nearly level surface, between heights of 4000 and 5000 feet. All parts of the plateau to the south of Kamloops Lake and east of the Thompson, afford good examples of this though the rocky sub-surface is here an irregular one. The Green Timber plateau may also be cited, though the nearly level floor produced by its basaltic sheets, may here be supposed in part to account for the uniformity of the boulder-clay which covers it. In such regions,

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several miles may often be travelled without finding a single projecting point of solid rock.

Respecting the thickness of the boulder-clay, even where its spread is greatest, it is impossible to make any general statement. It evidently fills certain hollows to a considerable depth and often runs out upon rocky prominences within a short distance with a feather-edge. It is probably in some places at least a hundred feet thick, but no single section was observed within the area of the Kamloops sheet which showed such thickness. This paucity of good sections is readily explicable, for it is probable that its persistence over the lower parts of the plateau is to be accounted for chiefly by the circumstance that it has there not been subjected in any great degree to denudation.

Thickness of
boulder-clay.

In the course of the examination of the region, I found myself becoming accustomed to note the occurrence of 'ordinary plateau boulder-clay.' A difference was in fact observed between the boulder-clay of the plateaux and that seen in some sections in the lower valleys, which though one of degree rather than of kind is pretty obvious in its character. This consists principally in the somewhat more sandy and silty nature of the boulder-clays of the plateaux, which becomes most marked towards the upper limit of the deposit. But these plateau boulder-clays are also generally paler coloured than those of the lower levels and usually present drab, fawn or yellowish tints. This is doubtless in part due to their greater porosity, which favours weathering and oxidation by surface waters, but also, probably, to the very slow removal of the weathered superficial portions on these areas. The only fundamental difference is, however, that in the original texture of the materials.

Boulder-clay
of higher
plateaux.

One of the best and most extensive exposures of boulder-clay, is found to the north of Pavilion Creek, about two miles eastward from the place at which the road begins its ascent to the Pavilion Mountain farms, and almost directly behind Captain Martley's house. A landslide which has occurred here on the upper edge of the valley, has produced a large bowl-shaped hollow, the bottom of which is strewn with great broken masses, while the sides present a cliff of about forty feet in height and several hundred feet in total length, composed almost entirely of boulder-clay. The material is here of a nearly uniform, pale yellowish-drab colour when dry, and so hard as to stand without much sign of waste in vertical faces of the whole height of the cliff. It is well charged with boulders and smaller stones of all sizes and of somewhat varied character, though granitic materials are most abundant. A considerable proportion of the stones are strongly glaciated. The

Exposures of
boulder-clay.
Pavilion
Mountain.

whole thickness of the boulder-clay here exposed, shows only very faint traces of any stratification or lamination, but it includes in its mass a few lenticular, horizontal and stratified layers of sand. Overlying the boulder-clay, is a variable thickness of stratified gravels, containing a few distinctly red layers. Above the gravels, and extending to the surface, is a thickness of a few feet of earthy material, constituting the soil. This is reddish and contains some stones and boulders. It has evidently been coloured by the decomposing Tertiary volcanic rocks of the vicinity, and may have accumulated by the washing down of the material resulting from this, together with that of the surface of the drift deposits proper, under the actual conditions. The elevation of the exposures of this place is about 3500 feet above sea-level.

North Thompson Valley.

Another excellent section of the boulder-clay, which may be described as typical of its general character, occurs in the North Thompson valley near the extreme north-eastern corner of the Kamloops sheet, on Coal Brook, a mile or rather more to the east of the river and some 200 or 300 feet above it, or 1500 feet above sea-level. One bank affords a section of about fifty feet, and the boulder-clay is also shown in numerous smaller exposures. The following description is quoted from my Report of 1877-78 (p. 140 B):—

"The matrix is a very hard, bluish, sandy clay, through which stones of all sizes are scattered in every position. These are chiefly of the rocks of the neighbourhood, but include numerous fragments of granite, not seen at this spot. Many of the stones are heavily scored and a few are very large; one, a mass of coarse granite, was found to be eleven feet four inches long, by eleven feet wide, and six feet four inches deep, the last dimension not fully shown. Notwithstanding the rough, or even tumultuous aspect of the deposit, traces of bedding are distinctly seen here and there, and near the top of the section a bed of clean-washed gravel about ten feet thick occurs. Above this, the boulder-clay, with all its usual characters, resumes for a thickness of three or four feet, and is again covered by horizontally stratified and false-bedded gravels which form the upper ten feet or so of the bank."

Bonaparte, near Ashcroft.

Another excellent exposure of the boulder-clay of the region is met with at the mouth of the Bonaparte, where the river enters the Thompson, about a mile and a half only distant from Ashcroft station on the Canadian Pacific railway, and thus easily accessible. It is described in another connection on a following page (p. 273 B).

These notes on individual exposures of the boulder-clay within the limits of the Kamloops map-sheet, may suffice to characterize this deposit,

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and no further mention need be made of the almost innumerable minor exposures met with in the district.

In the paper published in the Transactions of the Royal Society of Canada, to which reference has already been made, the general result of the investigation of many parts of the interior of British Columbia is thus given:—"Throughout the Interior Plateau the upward limit of the boulder-clay is found at a height somewhat greater than 5000 feet above the present sea-level, and corresponding in this respect with the highest level of well-marked terraces; the higher terraces in fact generally consisting of material identical in character with that of the general covering of boulder-clay, or so closely alike as to be indistinguishable from it. Though, as previously noted, travelled stones occur on much higher points, no boulder-clay, and very little fine drift material of any kind, has been found above the highest terrace-level above referred to."*

Coincidence of highest terraces and highest boulder-clay.

Various explanations may be offered of the general fact thus stated. It may be supposed, for example, that the boulder-clay by reason of its increasingly arenaceous character at higher levels ceases to be recognisable as such above a certain line, or that the naturally greater effect of denudation on the higher points has, in process of time, removed such deposits of boulder-clay as may at one time have occurred on them. As it is intended here merely to present the facts themselves, as clearly as may be from the evidence afforded by the area of the Kamloops sheet, no discussion of these or other hypotheses will be undertaken. It may be stated, however, that the proximately exact coincidence of the upper limit of the boulder-clay with the highest of the well marked terraces of the region, is apparently such as imply a common cause. No distinct boulder-clay has been recognized above the level of these higher terraces, and the main mass of the drift deposits of all kinds lies below it. As we have already seen, these deposits do not increase progressively in volume as we descend, but they are found in their greatest and most connected spread at levels between about 5000 and about 3000 feet.

Possible causes of this.

It appears reasonable to consider the wide-spread and nearly horizontal deposits of boulder-clay which frequently occur toward the higher limit of the main drift, as essentially of the character of terrace-flats, and as probably evidencing the contemporaneous or subsequent action of water, in the same manner as do the narrower terraces. Such flats are in fact often covered by a few feet of fine silty or earthy deposit, which seems to imply sedimentation of a comparatively tranquil

Terrace-levels composed of boulder-clay.

*Loc. cit., p. 36.

character, as a last event. Instances of such high-level flats of boulder-clay have already been cited.

Character of
upper limit.

It now remains, to describe the essential features of some parts of the upper level of the main development of drift deposits, by way of illustration of the character of this limit, and with special reference to the boulder-clay. It is, however, unfortunately not possible in all cases to ascertain the precise character or composition of the drift towards its upper limit, because of the infrequency or obscure character of the natural exposures, rendering a complete knowledge of the facts impossible and preventing a perfectly definite classification. It is also necessary, in so doing, to forestall in part what is subsequently said on the question of terraces.

Green Timber
Plateau.

The general surface of the Green Timber plateau, ranging in height from 3800 to 4000 feet, is thickly and very uniformly covered by boulder-clay, this in many places forms the actual soil, but is elsewhere covered by a limited depth of sandy deposits and is traversed also by moraine ridges (p. 279 B). The character of this boulder-clay, which is quite normal, is very well shown in numerous borrow-pits along the wagon-road. The plateau rises very gradually to the west, toward the Marble Mountains, all the higher parts of which consist of almost perfectly bare rock, but of which the entire base, with a length of fifteen miles, is thickly heaped with drift deposits. As viewed from any part of the plateau at a considerable distance, the upper line of these deposits appears to be perfectly definite and straight and is very strikingly outlined.* On approaching the southern part of the range, near the upper parts of Clinton and Sandy creeks, the boulder-clay becomes covered with sandy deposits, some miles before the actual base is reached, at a height approximating to 4500 feet. These deposits increase in importance, till near the base of the mountains they appear as horizontally stratified terrace-flats, fifty feet or more in thickness as shown in the banks of Sandy Creek. Above this, are still higher, though narrow, terraces which were distinctly traced at this place to an elevation of about 5500 feet. Morainic mounds and ridges, showing gravelly material and some boulders on their slopes but not seen in section, are associated with these higher terraces, in such a way as to show that the terraces are of later date and have been formed in part by the levelling and redistribution of material derived from the moraines.

Northern part
of base of
mountains.

The northern part of the same base of the Marble Mountains, was examined to the south-west of Big Bar Lake. The plateau here rises

*Compare the sketch of Il-ga-chuz Mountain, much further north, Quart. Journ. Geol. Soc., vol. XXXIV., p. 100, Fig. 5.

somewhat less gradually toward the base of the mountains, and the conditions observed were not absolutely identical with those in the first-described vicinity. The height of Big Bar Lake is 3630 feet, and about its upper or southern end, moraine ridges are observable to a height of about a hundred feet above it. Higher than these and nearer to the mountains, a wide sandy and gravelly terrace-flat is crossed, which slopes gradually up from a level of 4000 feet to one of about 4300 feet. Beyond this, a considerable width of moraine country is again found, in which the general direction of the ridges is parallel to the base of the range. Higher than these moraines and running back to the mountains, is a second terrace with a height of 4700 feet. Other smaller terraces with narrow treads occur still higher, to an elevation in this place of about 5100 feet. The impression conveyed by the conditions observed here is, that the several tiers of small moraines had been produced by temporary periods of advance of a glacier-mass, which, on the whole, was shrinking back to the north-westward from the then submerged area of the Green Timber plateau.

Near a local summit on the Tranquille plateau, due south of Tranquille Lake, a terrace occurs with a height of 5340 feet. This is perfectly distinct and somewhat extensive, and was seen, from a distance, to be repeated on the southern slope of Porcupine Ridge, some miles to the northward and beyond the lake. Where examined in 1889, this terrace was found to be composed of boulder-clay or identical material. In 1890, about three miles to the eastward, near the head of Watching Creek, a series of narrow but distinct terraces which can be traced for a mile or more in length, was noted. These extend in height from about 5300 to 5450 feet, and are composed, so far as could be ascertained, of rounded and sub-angular gravels mixed with earthy material, the gravel being more abundant than in most true boulder-clays. The slopes to the north of and above these terraces are but thinly and irregularly covered with drift material.

In-ki-kuh' Creek, which joins the Thompson from the eastward five miles above the Nicola, falls very rapidly in its lower part toward the great valley of the Thompson, but at about five miles and a half from its mouth and thence to the lake at its source, occupies a wide low-grade valley on the surface of the plateau, at an elevation of about 4500 to 5000 feet above the sea-level. The lower part of this valley opens in a flaring manner toward the Thompson, and there is no probability of its having been at any time locally stopped. The country on both sides of the upper part of the stream, is thickly covered by drift, the greater part of which is of the nature of boulder-clay. The surface of this deposit rises gradually with the slope of the valley, till just

Tranquille
Plateau.

In-ki-kuh'
Valley.

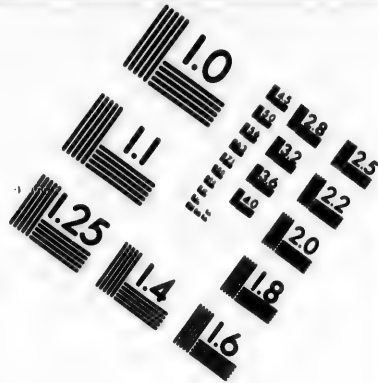
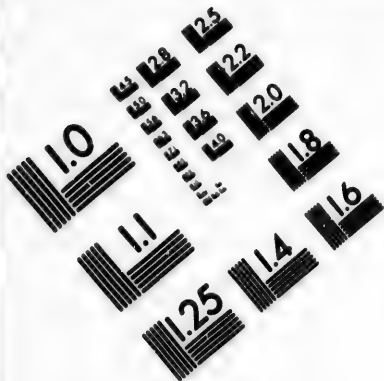
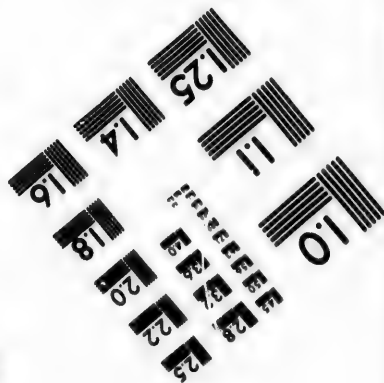
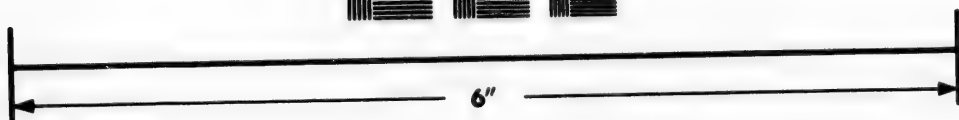
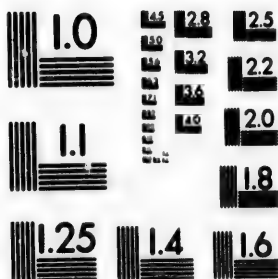


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below the lake and practically at its level (4920 feet) it forms a flat terrace-like floor. The rocky hills to the south of the lake beyond, are heaped with drift deposits to a height of about 200 feet above it (5100 feet above sea-level) and these, from a distance, show a pretty distinct upper line, which might almost be designated as a terrace-level, though it was not closely examined. The hills above this level consist of nearly perfectly bare granitic rock.

Choo-whels"
Mountain.

From the extensive development and wide spread of deposits of boulder-clay to the south of Choo-whels' Mountain, and the gentle slopes of the mountain itself, it was hoped that some definite information as to the precise upper limit of the boulder-clay might there be obtained, but this hope was not realized. The mountain was ascended on the south-west side and descended on the opposite slope. The highest distinct and wide terrace was passed over in ascending at 4240 feet. This is composed of boulder-clay with a silty covering, sometimes not more than two feet in thickness. True boulder-clay was noted, where the roots of trees had been overturned, for some distance above this, but at heights exceeding 5000 feet, a great part of the whole surface consisted of solid rock, with small intervening drift-filled hollows and valleys. The stones here contained in the boulder-clay are, as usual, more or less distinctly rounded, but become increasingly angular at higher levels. Toward the summit, where occasional exposures are found of the superficial deposits, these consist of earthy materials mingled chiefly with angular stones of proximately local origin. The actual south-western summit-point of this prominent elevation on the plateau, has a height of 6000 feet. It is partially covered with drift of the character just described, and the rock-surfaces, though much weathered, have been heavily glaciated. The faces which still showed the original striation, indicated (as previously noted) a direction of S. 35° E.

Heavy drift
unusually
high on Sil-
whoi'-a-kun
Plateau.

The most notable exception to the general rule of the extreme paucity of drift deposits above a level which approximately coincides with the 5000-foot contour, is found in the Sil-whoi'-a-kun Plateau. The wide elevated portion of the plateau to the west of the North Thompson so named, is more thickly covered with drift material than any other region of equal height which has been examined. The drift is moreover pretty uniformly spread upon its surface. There is, however, reason to believe, from the very frequent outcrops of rock, the generally local character of the boulders and the hard bouldery beds of the small streams and rivulets, that it is rather in consequence of the uniformity and the undenuded state of the drift material than to its thickness that its apparent importance is attributable. This again

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doubtless depends on the wide surface of this higher part of the plateau. As to the precise character of the drift covering here, no very satisfactory information was obtained, as it was seen only in the upturned roots of trees. These showed a yellowish earthy and sandy material, packed with stones, which are commonly angular, and largely fragments of the subjacent rocks. Travelled stone and boulders, generally of gray granite, are also, however, scattered over all parts of this elevated volcanic plateau. The particular mention accorded to Sil-who'i'-a-kun, is chiefly for the purpose of noting its somewhat exceptional character, as compared with that of the numerous other places upon which the general statements before made are based.

The foregoing details refer especially to the character and elevation of the boulder-clay at its upper limit. It appears probable that the higher parts of the district were never covered with true boulder-clay. In whatever manner the boulder-clay was produced, it seems reasonable to suppose that in the lower parts of the district a thickness at least equal to that found at intermediate elevations must originally have been laid down, and highly probable that such lower tracts received an even greater mass of this deposit. As a matter of observation, it is found that exposures of boulder-clay are comparatively seldom met with in the lower and larger valleys of the Fraser and Thompson, included in the Kamloops sheet. This is no doubt in part due to the great development of newer terrace deposits in these lower tracts, but only in part, for very numerous and often almost continuous sections occur that are cut down to the solid rock along the rivers and their tributary streams. Further, with the exception of those parts of the larger valleys which are occupied by terrace accumulations, the slopes of these valleys are not usually thickly covered with drift deposits of any kind, and projecting points and large surfaces of rock are everywhere abundant.

Paucity of
boulder clay
in lower
valleys.

From these circumstances, I believe we are warranted in concluding that the greater part of the boulder-clay which must have been deposited in these lower valleys, was at a later period removed by denudation. On referring to what has been said in the introductory part of this portion of the report, (p. 251 B) it will be seen that I am inclined to regard this epoch of denudation as contemporaneous with, and as the result of, a considerable relevation of the land, which is also supposed to have been synchronous with the second period of increase of glacier ice. It is believed that the height at that time attained by the land, was such as to enable the larger rivers not only to reexcavate their valleys, but also to remove great quantities of new material which would

Its removal
thence by
denudation

doubtless be carried into them from the adjacent slopes by tributary streams and by superficial agencies. /

Observed
sections in
Fraser and
Thompson
Valleys.

Without, however, insisting on the accuracy of this interpretation, I may now explain the nature of the facts upon which it is based. Of these, the most obvious, is that already referred to, *viz.*, the evidently small importance of the deposits of boulder-clay now remaining in the lower valleys. While it is probable that traces at least of this material may exist in that part of the length of the Fraser Valley which is included by the map, I am unable to mention any single exposure in which it is shown, and it was in connection with the examination of this valley, in 1889, that its notable absence first became apparent. In the Thomson Valley, between Kamloops Lake and the confluence of that river with the Fraser, while boulder-clay is scarce, it is not altogether wanting. Near Black Cañon, three miles and a half below Ashcroft, typical boulder-clay is seen in several places in cuttings along the railway, and considerable exposures are found about the mouth of the Bonaparte, a mile and a half above Ashcroft. These are the only occurrences actually noted, though close search along other parts of the valley would doubtless result in the discovery of others.

The denuda-
tion of inter-
glacial date.

Granting, therefore, that the greater part of the mass of the boulder-clay originally deposited in these valleys has been in some way removed, and of this the evidence appears to be conclusive, it remains to assign a date for this removal relatively to the other phenomena of the glacial period. It might be suggested that the clearing out of these valleys occurred during the period of considerable elevation of the region which there is good reason to believe supervened at the close of the glacial epoch, and was thus merely a part of the post-glacial valley erosion which is subsequently alluded to. The occurrence and relations, however, of the White Silt deposits (also referred to in greater detail on a later page) in many parts of these valleys, negatives this supposition, and shows that the removal of the greater part of the boulder-clay must have occurred previous to the deposition of these silts, the origin of which is clearly glacial, and the period pretty distinctly that of the decline of the second maximum of glaciation. This conclusion follows so obviously from the general circumstances, that it was arrived at and used as a basis of reasoning in my paper in the Transactions of the Royal Society of Canada already referred to. Since that paper was written, additional evidence of the same kind has been met with, of which two instances may now be particularly noted.

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The first of these, is that afforded by the sections shown in bluffs on the north side of the Bonaparte at its confluence with the Thompson, of which a diagram is here presented. The bluff rises to a height of

Section on Bonaparte showing this.



FIG. 10. SECTION ON THE NORTH SIDE OF THE BONAPARTE, AT ITS MOUTH.

- | | |
|--|------------------------|
| 1. Boulder-clay. | 4. Old river-bed. |
| 2. Stratified gravel. | 5. Stratified gravels. |
| 3. White silt. | 6. Silty soil. |
| 7. Second old river-bed, covered by stratified gravel. | |

about 200 feet above the river, its upper limit being formed by a terrace-flat of about that height. Of its lower part, about 50 feet is concealed by a late river-terrace, but most of the remaining height of 150 feet is well exposed. The greater part of the entire section here consists of boulder-clay. (1) This is of the usual character, containing some large boulders and many smaller stones, and is so hard as to stand in vertical faces. It includes, however, layers, some of which are two feet in thickness, of hard, silty material, horizontal or proximately so, and lenticular, not exceeding a few yards in extent. There are also similar traces of local horizontal bedding afforded by occasional sandy layers separating the general mass. No. 2, the deposit capping the boulder-clay, is a stratified gravel, composed of medium-sized and small stones like those in the boulder-clay, but more perfectly rounded. The upper part of this bed is a clean gravel, but its lower part is clayey from included material - the boulder-clay paste, and it is in consequence not always easy to fix the exact line of junction of this deposit with the boulder-clay. No. 3 is typical White Silt, with the usual creamy tint of this deposit, well and regularly stratified in thin layers and rather hard, though it may be crumbled easily between the fingers. Overlying this is No. 4, a coarse, gravelly and bouldery river-bed deposit with well rounded and polished stones, indicating a strong current, and precisely resembling the material of the bed and beaches of the adjacent part of the Thompson. No. 5, consisting of finer stratified gravels, overlies this, and gives to the surface of the terrace-flat its level form. Resting on No. 5, and forming the actual surface of the terrace, is a thin layer of silty soil. At No. 7,

Position of White Silt.

occurs another thin deposit of river-bed material like No. 4, again covered with gravels like No. 5.

The sequence of events indicated by the section thus described is believed to be as follows:—

Events indicated by sequence of deposits.

Silts and Gravels.

Post-glacial erosion.

Conditions in Tranquille Valley.

Subsequent to the deposition of the boulder-clay, this material was greatly denuded and in large part worn down, and the resulting debris removed. This action was brought to a close by a following submergence, during the progress of which, and while some parts of the boulder-clay were still exposed, stratified gravels (No. 2) were formed. With an increased depth of submergence, the deposition of the White Silts (No. 3) began and a great depth of material of this kind, was laid down, implying a prolonged tranquil period. In this particular section, merely a feather-edge of the White Silts has been preserved, but on the opposite side of the Thompson a similar material forms a considerable part of the entire height of the bank, without any apparent boulder-clay. (p. 306 B.) Similarly, about a mile further up the Thompson on the same (west) side with the section here particularly noted, the silts form a range of cliffs along the river about 350 feet in height. The material found here is not however all silt, but includes numerous beds of gravel due to inwash from the adjacent hills or streams, and resembling in character the gravel (No. 2) in the section. At a still later date, the flooded condition of the valley ceased, and the White Silts themselves became subject to erosion by the river, which resumed its course. This was doubtless in post-glacial times, and the river deposit (No. 4) represents the old bed of the Thompson, at one stage in its descent through the glacial material to its actual level. The overlying gravels (No. 5) are those of a flood-plain of the river at a slightly subsequent date, while the silty capping is a still later deposit on the same flood-plain, produced at a time when the river seldom attained to its level. The deposits at No. 7, represent part of the bed of the river at a still later stage in the process of post-glacial erosion, when it had cut down about a hundred feet lower than the level of No. 4.

The most important point illustrated by this section, is of course the relation of the White Silts to the boulder-clay and to the interglacial period of denudation, on one hand, and to the much later post-glacial erosion on the other.

A second illustrative case, is afforded by the conditions of the lower part of the Tranquille River, though in this instance the whole series of events is not so clearly shown as in the last. The Tranquille River, above the point at which it debouches on its wide delta-flat, flows for several miles in a deep cañon-like gorge or narrow trench, cut out along

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the axis of a much wider valley, of which the bottom-level, at some miles back from Kamloops Lake, has a pretty uniform height of about 800 feet above that lake. The newer and narrow valley, has been completely filled with drift material referable to the period of deposition of the White Silts, and in post-glacial times has been re-excavated by the stream, which has even been able to cut to a small additional depth into the rocky bottom of the old valley. The drift material referred to, still, however, remains in some parts of the narrow valley, in the form of steep banks or cliffs, in height nearly equal to the whole depth of the gorge. It consists principally of firm beds of gray gravel, but these hold important intercalations of White Silt of the usual character, and quite distinctive enough to fix the date of the deposit as that of the White Silt formation generally. The gravelly character of the beds at this place, is in fact evidently due to the local supply of coarser materials washed down into the body of water in which the silts were in course of deposition, a circumstance frequently observed elsewhere.

No true boulder-clay was met with in this narrow part of the Tranquille Valley, but it cannot be doubted that if the gorge existed in pre-glacial times it must have been filled with boulder-clay, and that this was worn out subsequently by the stream during the time intervening between the period of the deposition of the boulder-clay and that of the White Silts. If, on the other hand, it be supposed that the gorge is not pre-glacial, but was cut out in the rock during the same intervening time, it equally implies that this was one of considerable elevation, and would tend to show that it was even more important and longer continued than it would be necessary to believe under the first and more probable hypothesis.

Excavation
subsequent to
boulder-clay.

Another circumstance, which may be mentioned in this connection, is the occurrence in several instances along the Thompson and Fraser, of noteworthy accumulations of heavy boulders, opposite the mouths of some of the tributary streams and forming true cones of dejection at these places. It is difficult to determine at precisely what epoch these accumulations were formed, but their relations lead me to believe, that this happened at a time previous to that at which the greater part of the terrace-material now occupying these valleys was deposited, and under circumstances in which, though excessively heavy flood-waters were occasionally discharged by the tributary valleys, the main valleys were not themselves river-courses. To comply with the last-mentioned condition, it is obvious that the lower and larger valleys must have been deeply flooded, and it is therefore highly probable

Cones of
dejection in
larger valleys.

Their date.

that the boulder-cones were produced after the time of the main denudation of the boulder-clay in these valleys, and during the earlier stages of the following submergence which resulted in the accumulation of the White Silts.

On Thompson River.

The most instructive case of this kind noted, is that on the Thompson four miles above Spence's Bridge, opposite the mouth of Pimainus Creek. The Thompson Valley is here excavated in Tertiary volcanic rocks, while the material brought down from the valley of the Pimainus is almost entirely granitic, and is thus easily recognized. The cone of dejection has here evidently spread from the mouth of the Pimainus, quite across the wide valley of the Thompson, to the bases of the mountains on the opposite or west side. In following the wagon-road on that side, the great accumulation of heavy granitic boulders, in some cases at least six feet in diameter and massed together at a height of 200 feet or more above the present river, is very notable. What still remains there of the outer part of the cone, is now, however, separated from the east side of the valley by the whole width of the later immediate valley of the Thompson, and in being cut through at this later time by the river, it has been made to assume the form of rough, bouldery terrace-flats. On these, the thickly strewn boulders have been rounded, worn and polished, while the river flowed at their level, and before it had succeeded in re-excavating its bed to its present depth. During this process of re-excavation the river has carried granitic material derived from the old cone along its course, and in following the river down, this material is found to decrease gradually in amount and in the size of its constituent fragments.

On Fraser River.

At the mouths of Ni-kai-a and Kl-ow'-a creeks, below Lytton on the west side of the Fraser, similar cones of dejection containing some very large boulders were noted. The mountains in which these short streams rise, consist of granitic rocks, which break up with facility into boulder-like masses, but no flood-water ever now occurring will account for the carriage of such large masses as those which have been brought down under former conditions. It is probable, that these and other similar cones of dejection along the Fraser, are referable to the same period with that above described. Some further allusion is made to such cones and 'fans' in connection with the history of the Fraser Valley (p. 303 B).

Terraces and Stratified Deposits newer than the Boulder-clay.

Interlocking of phenomena.

Under the last heading, particular attention has been given to the boulder-clay, with the facts bearing on its limit in elevation, or ex-

plaining its relative scarcity in the lower and larger valleys, in which, other things being equal, we might reasonably have anticipated that it would be found in its greatest development. The various phenomena of the glacial period are, however, so closely interlocked, that in following the subject of the boulder-clay it has been necessary to introduce the consideration of some other topics, and in part to anticipate, by allusion to them, some of the deposits which are considered in greater detail in following pages. A strict separation of the different parts of the subject, could be arrived at only by the adoption of some ruling hypothesis, which in this description of the phenomena it is my purpose to avoid as much as may be possible.

The more important terraces observed in the area of the Kamloops sheet are enumerated below. The observations are given in the order of their height, beginning with the highest, and it may be explained that the terraces here mentioned, unless otherwise stated, are believed to represent old shore-lines. The higher terraces which appeared to be of this character were carefully noted, but those which could be explained on the spot as being due to strictly local causes, such as local moraine dams in small valleys, and the valley-terraces of streams running upon the plateau, are not included. Neither are the river-terraces of the larger and lower valleys here enumerated, though terraces of this class continue to occur at all levels in the district below those with which the present list terminates. After descending to a certain level in these lower valleys, it became difficult to discriminate between terraces representing shore-lines proper, and which may either have been cut out in preëxisting drift deposits or built up by inwash from the adjacent slopes along a shore-line, and those which have been produced by the actual rivers while these were engaged in re-excavating their valleys in post-glacial times. The terraces of the latter class have a meaning of their own, in relation to the later history of the rivers. The list which follows, scarcely includes any of the low-level terraces, which form such a striking feature of the scenery of the Fraser and Thompson valleys, and cannot escape the notice of the traveller who may pass through the district on the line of the railway. They have been observed under varied conditions, being sometimes clearly seen for miles at a time, on open grassy slopes along the edges of parts of the plateau, at others crossed in dense woodland or found patched upon the more prominent summits of the plateau or mountains adjacent to it.

The list of terraces.

Lower-level terraces not included.

It is, therefore, not possible to ensure that all the observations are of a strictly comparable character, for while in some places such terraces may have but a narrow tread, and are, therefore, susceptible of

Different values of terraces.

definition in regard to height with considerable accuracy, other cases occur of wide terraces sloping gradually back from a frontal edge, which may now be imperfectly defined, to a considerably higher level. Besides these here particularly enumerated, there are also many faintly impressed water-lines locally preserved, and often apparent from a distance on open slopes, particularly at elevations inferior to 3000 feet. An easily accessible example of this kind, which enables the lowering of the water-level by a uniform process, or one with but short stationary intervals, to be traced, is found on the north side of Paul's Peak, near Kamloops. On this grassy slope, under favourable conditions of light, a complete descending scale of such small terraces may be seen.

Heights baro-
metrically
ascertained.

The heights given below have been barometrically determined within small limits of error, by comparison with a station barometer at Kamloops, the reduction of the various observations having been made in the same manner with that of those upon which the contour-lines of the map depend.

List of the higher Terraces observed within the area of the Kamloops Sheet.

	Feet above sea-level.
1. East side Marble Mountains, north of Clinton Creek (p. 268 B).....	5500
2. Near head of Watching Creek valley (p. 269 B) 5300 to about.....	5450
3. Slope of Mount Murray, a small and irregular but still distinct terrace.....	5380
4. West side Marble Mountains, twelve miles north-west of Kelley Lake, about.....	5360
5. South-east side Lytton Mountains, apparently a distinct terrace-flat on slope of Fraser Valley.....	5340
6. On plateau near Tranquille Lake (p. 269 B).....	5340
7. East side Marble Mountains, north end, near Big Bar Lake (see No. 9) about.....	5100
8. Head of Big-fish Lake, Greenstone Creek. A small terrace, which may be due to local ice-damming or moraine-damming of the valley.....	5000
9. East side Marble Mountains, north end (p. 269 B), same locality as No. 7.....	4700
10. South of lower part of Meadow Creek.....	4700
11. Murray Creek. Terrace in valley, doubtfully due to local causes.....	4450
12. Point of plateau between Meadow Creek and Guichon Creek. Well marked wide terrace, of which the surface shows evidence of current-action contemporaneous with or subsequent to its formation. Direction of current indicated S. 50° E (See p. 293 B).....	4400

	Feet.
13. Plateau between head of Skuh'-un Creek and Mamit Lake. Terraces associated with moraines	4396
14. Valley of Ray Creek, a tributary of Guichon Creek ..	4350
15. Meadow Creek valley, north side, near mouth of Greenstone Creek, about	4350
16. In-ki-kuh' Creek. Terrace-flat (p. 269 B)	4330
17. Western slopes of Trachyte Hills, near Flat Creek ..	4300
18. Plateau west of Trout Lake. Terrace-flat composed of boulder-clay	4240
19. Plateau between heads of Guichon and Three-mile creeks. Distinct terrace	4150
20. Green Timber Plateau. Sandy terraces and terrace-flats between morainic ridges	3900 to 4150
21. Highland Valley near watershed. Terraces several hundred feet above moraines in valley	4000
22. Guichon Creek valley, west side, below Witches Brook. Terraces traceable for several miles, about	4000
23. East base of Marble Mountains, north end. (See No. 9.) Wide terrace-flat sloping gradually down from moraine ridges at 4300 feet to	4000
24. Point of plateau between Pukaist and In-ki-kuh Creeks ..	3730
25. Guichon Creek valley below Witches Brook, west side. Terrace traced several miles at lower level than, but in part overlying, moraine ridges. A second development of moraine ridges at lower level, between this terrace and the creek	3590
26. Dome Hills, near Kamloops	3500
27. Hat Creek valley, west side, near east end Marble Cañon. Wide terrace. (See No. 32)	3360
28. Upper Guichon Creek, above Witches Brook. Terraces and contemporaneous moraines	3350
29. Lower Guichon Creek, below Mamit Lake. Terraces and moraines, about	3250
30. Ridge east of Paul's Peak. Large flat drift-covered area	3250
31. Lower part of Upper Nicola valley, near lake. Terraces rather faintly impressed but traceable for many miles. (See No. 39)	3080
32. Hat Creek valley, west side, near east end Marble Cañon. Wide terrace below No. 27	3070
33. South of Jacko Lake, about	3050
34. South of Jacko Lake	3000
35. One mile west of Jacko Lake. Terrace-flat	2790
36. Near Newman's, Trapp Lake. Wide terrace	2580
37. Twaal Valley. Terrace composed of silty material ..	2500
38. Nicola Valley, at lower end of Nicola Lake. Best marked of several terraces	2470
39. Lower part Upper Nicola Valley, near lake. Important terrace of same series with No. 31	2450
40. Inner Valley, near Kamloops. Highest terrace locally recognized	2400

Comparison of
terraces.

An inspection of the above list of observed terraces or shore-lines, will show that these occur, within the area of the Kamloops sheet, at many different levels from a height of 5500 feet down. The list might doubtless be largely added to by further and more minute examination of the area in question, but the actually recorded observations are sufficient to indicate the general character of the facts as they occur there. Considerations already referred to, render it impossible to institute any very exact comparison between the heights of terraces in different parts of the field, and in order to investigate the questions which might be found to depend on such comparison, it would be necessary to spend much time in following out individual terraces, in a manner not yet attempted. In order, however, to arrive at such general ideas of correlation as the observations might warrant, these were graphically represented together on a single sheet. An examination of the levels of the various terraces as thus assembled, brings out a marked tendency of the observed levels to group themselves about several points, at or near which it is to be presumed that the water stood for a longer period than at intermediate elevations. It also shows, that no very long interval in the whole scale is altogether without terraces, even when the evidence considered is limited to that obtained in the area of the Kamloops map-sheet.

Highest
group.

The highest recognized terraces appear to form one such well-marked group, the observations regarded as belonging to which are those included between about 5500 and 5300 feet (Nos. 1 to 6 of list). The observations on terraces of this highest group are scattered over a considerable area of the map, and are moreover supplemented and extended to a much wider area by some made beyond the Kamloops sheet which have been elsewhere discussed.*

A few scattered observations at less considerable elevations, intervene between those included above and those of the next considerable group of terraces. Of these intervening terraces, No. 7, with a height of about 5100 feet, met with on the eastern base of the northern end of the Marble Mountains, is similarly situated to No. 1, and there is reason to believe that it belongs to the same series of terraces, which, running along the base of the Marble Mountains, overlooks the Green Timber plateau. No. 9, again occurs in the same locality with No. 7, and probably forms a lower member of the same descending series, and one for which there is no apparent reason to suppose any different mode of origin. This and that numbered 10, it will be

* Trans. Royal Soc. Can., vol. VIII., sec. IV., pp. 36, 37. See also Bull. Geol. Soc. Am., vol. VII., p. 31.

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observed, are identical in height. The terraces numbered 8 and 11 may possibly be due to strictly local causes.

I have referred thus in detail to these observations relating to certain terraces below these which have been included in the above "first group," as preparatory to the statement that the most notable gap in the whole series of such shore-lines is that which occurs at about this place. The extent of this gap, or interval in which few terraces are known, may probably be approximately defined as occurring between 5300 and 4450 feet. In order further to illustrate the paucity of shore-lines in this interval, it may be added that, in the whole interior of British Columbia, I have recorded but three instances of terraces within the limits just stated, in addition to those above cited from the area of the Kamloops sheet. These are Mount Tod, 5116 feet, or practically identical with No. 7; Prospect Creek, 4660 feet; Dease River Valley, 4600 feet.* Of these the first is supposed to belong to the "first group," and the second is very probably identical with that represented by Nos. 9 and 10. Both these are situated but a few miles beyond the edge of the Kamloops sheet. The third is so far distant to the north-west, that no argument can safely be based on its seeming relation to the others.

Notable gap
in scale of
terraces.

The apparent connection of several of these "intervening terraces" with those of the rather well-marked "first group," as abnormally low members, due to the same series of events or produced in the same manner, has already been referred to. A consideration of this and the other facts above noted, and more particularly of the occurrence of the rather well-marked break in the continuity of the entire series of terraces which has been alluded to, led me in a former publication to suggest the origin of the terraces of the "first group" with the scattered lower dependant terraces, to what I have called englacial lakes, and to attribute the whole system of terraces below this break to different causes, but no further argument on this point need here be entered into.†

Lower
members of
highest group.

A second group of terraces or shore-lines, which appears to be fairly well marked out by observations in the area of the Kamloops sheet, may be defined as running from 4450 feet to 4300 feet, embracing the entries numbered 11 to 17, both inclusive. These observations are derived from the whole valley of Guichon Creek, and parts of the adjacent plateau, the Thompson Valley below Ashcroft, and the wide upper valley of Hat Creek. The terraces included in this group are important, and are often traceable for considerable distances, but the

Second group
of terraces.

* Cf. *op. cit.*, pp. 36-37.

† See, in this connection, foot note to next page.

lower limit, at least, must be considered as scarcely more than arbitrary, as no marked break again occurs in the descending series. Beyond the Kamloops map-sheet, within British Columbia, I know of only two instances of terraces which are included between the limiting heights given for this group, and these are too far removed by distance to be employed as any basis of argument.

Various
correlations.

The succeeding terraces enumerated, from No. 18 to No. 23, both inclusive, show a general correspondence between the region of the Green Timber plateau, and that in the valley of, or on parts of the plateau adjacent to, Guichon Creek, with a marked development of important terraces at a level of about 4000 feet.

Numbers 27 and 28, in the wide valleys of Hat Creek and Guichon Creek respectively, are practically identical (3360 and 3350 feet), while Nos. 30 and 31 in the Nicola Valley (which is freely in communication with the Guichon Creek valley) and Hat Creek valley respectively, (3080 and 3070 feet) seem to form a similar but lower pair, and to indicate similar periods of arrest in the subsiding water-line in both these rather widely separated places.

The association of some of the terraces at levels of 3350 and 3250 feet in the Guichon Valley (Nos. 28 and 29) with morainic ridges, is mentioned in the list, and though at some distance to the south of the Kamloops sheet, it may be added that in valleys and on low tracts of the plateau to the east of the Coldwater River, a similar association is found at closely corresponding elevations, or between 3300 and 3200 feet approximately.*

* Since this part of the report was written (1893) an entirely independent re-examination has been made of the glacial deposits of the south-western part of Alberta, to the east of the Rocky Mountains and along the western margin of the Great Plains: a district removed by nearly 300 miles in distance from that here particularly described. This has developed so striking a general parallelism between the higher terrace-levels of the two districts that it seems necessary to allude to it, although inappropriate here to enter into a discussion of the wider questions which it appears to raise, including the probability of a general subsidence of land much greater in amount than that postulated by the provisional scheme of events given in the first part of the present chapter. The main conclusions respecting the terrace-levels of south-western Alberta, may be best conveyed by quoting the following paragraph from the paper dealing with that subject:—"All the later and lower terraces and gravel plains may be regarded as marking stages in the subsidence of this water-level from its maximum height of 5300 feet. These, it has already been noted, are usually not strongly impressed, and there is no evidence that the subsidence was arrested long, except at one stage, which is that spoken of in the report of 1882-84 as being at about 4200 feet. Further examination shows that the terraces referable to this particular stage slope up gradually in the foot-hills, and on approaching the mountains, to a maximum height of about 4500 feet, from which it may be argued that from the last-mentioned height the water lowered its level gradually to one of about 4200 feet, while new material was constantly being washed down by rivers from the mountains. A later and still lower, though less important, period of arrest, seems to be marked by the gravel plain near Macleod at about 3200 feet." (Bull. Geol. Soc. Am., vol. vii, p. 63.)

No better examples of the lower terraces of the region (excluding river-terraces) can be found than that presented by the hills near Kamloops (1150 feet). Behind the town, particularly in an afternoon light, the grassy slopes on both sides of Peterson Creek are seen to be ruled by parallel shore-lines at several different elevations. In ascending these hills by the road, the level of one of the highest terraces in this immediate vicinity, is very clearly seen on the eastern slope of the ridge to the north, near Guerin's, where it is marked by the lower edge of the wooded growth. Its elevation is 1900 feet above sea-level, and near Guerin's house, on the road, it is found in a more or less denuded and hummocky condition, to be characterized by well rolled gravels and stones, with some sandy and earthy matter. This particular terrace is, very probably, that representing the margin of the body of water in which the White Silts of the vicinity were deposited.

Examples of
lower terraces

Continuing southward from Guerin's, across the hills, to the neighbourhood of Jacko Lake, higher terraces are discovered at many different levels, often occupying retired angles and valleys, but none of them by any possibility due to purely local causes. Near the small hour-glass-shaped lake to the south of Jacko Lake, the highest terraces actually seen in this vicinity were observed, at levels of about 3000 and 3050 feet above the sea respectively.

White Silt Formation.

The terraces and shore-lines enumerated in the foregoing list, and to some of which the explanations just given apply, are in part of the nature of accumulations built up along the edges of water, and in part have been cut out of still earlier drift deposits by the erosive action of the margin of the water. In many cases the information is not sufficient to determine the precise mode of origin of any particular terrace, and in some instances both processes have no doubt coöperated in producing a terrace. At levels lower than these included in the foregoing list, terraces of both kinds continue to occur, and a considerable proportion of the terraces of erosion are known to be true river-terraces, formed by the rivers and streams when engaged in reëxcavating their beds in post-glacial times. The interest attaching to these is chiefly in connection with the history of the modern river-valleys. From about the level of 2500 feet downward, a notable development of pale silty deposits is found in many parts of the area of the Kamloops sheet. These deposits have originally been much more extensive than they now are. They are sometimes still found to completely floor the valleys, but in most cases remain as terrace-like fringes along the sides of

White Silt
terraces.

valleys in which the river has since cut a deep median trough, and not infrequently, but small traces of the original deposit are preserved, clinging to the sides of the valleys, or occupying sheltered recesses along the bases of the plateaux.

Nature of the deposit.

These White Silt deposits are very widely developed throughout British Columbia, and their character and probable meaning has been discussed at some length in the paper which has been already several times referred to. The following general remarks on the White Silts are quoted from this paper* :— "In the regions characterized by them, which are in almost all cases at a less elevation than 2500 feet, these White Silts very often rest directly upon the boulder-clay. They are generally fine and uniform in texture and are usually well bedded in perfectly horizontal layers of an inch to two or three inches each in thickness. Where occasional sandy or gravelly layers are intercalated, these are attributable to local causes, being most frequently found opposite the mouths of valleys down which streams have flowed.

*Correspondence of levels shows common cause.

* * * The silts have evidently been laid down, as a rule, in tranquil water of considerable depth, and their material has as obviously been supplied by streams or rivers discharging from glaciers not far removed. In physical characters the silts resemble the deposits of the Red River valley, though usually in the Cordilleran region paler in colour, and seldom so clayey as those of some parts of the Red River. They differ from Loess chiefly in their well-bedded character. It is believed that the general correspondence in elevation of the various and more or less separated bodies of water in which this White Silt formation was formed, in itself constitutes a strong argument in favour of the hypothesis that these bodies of water were in direct communication with the sea and were governed in their level by that which it held at the time. No traces of morainic or other barriers have been found in any case sufficient to account for the damming back of water at the requisite level, nor do the local circumstances admit the supposition that such water was held in by glacier dams. Had the silts been formed merely in lakes produced in one or other of the modes last mentioned, they might be expected to occur, in a region with such strongly marked features as that of the Cordillera, at a variety of very different levels, in correspondence with circumstances varying in each particular case. The length of the period required for the deposition of a great thickness of these fine beds, also affords reason for belief in a long epoch of stable conditions, and to some extent justifies the presumption of the proximate contemporaneity of such a stable period. On

Long tranquil period.

* *Op. cit.*, p. 44.

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following the silt formation toward the various mountain ranges and sources of local glaciers, it is almost invariably found to be cut off somewhat abruptly before the mere increase in elevation would account for its disappearance. This circumstance, may, with very little doubt, be attributed to the fact that during the deposition of the silts, these upper parts of valleys were occupied by the still considerable local glaciers of the second period, which were engaged in producing the material of the silts. The evidence is, further, conclusive that these glaciers in the end retreated pretty rapidly, leaving, in many cases, the long trough-like valleys which they had occupied, almost entirely free from debris or detrital matter of any kind, and ready to become the beds of fiord-like lakes.**

Relation to
glaciers of
second period.

The following more particular notes from the same source,† refer to the southern part of the Interior Plateau generally and in great part to the area of the Kamloops sheet:—"In the southern part of the Interior Plateau region, in consequence of the considerable height of the mean level of the country, the White Silt formation is usually confined to the various trough-like valleys. It may be seen from the line of the Canadian Pacific railway, in characteristic development, forming frayed terraces along the South Thompson valley for a number of miles east of Kamloops. It is found also along Okanagan Lake, but in the southern continuation of the Okanagan Valley, near the forty-ninth parallel, is chiefly represented by fine sands. Along the lower part of the Similkameen it has been observed in patches. On the Nicola it is often well displayed. It extends down the main River Thompson to about the mouth of the Nicola, and appears again characteristically developed along the Fraser to the west of Clinton. It stretches far up the North Thompson, and runs back along the valleys of the main tributaries of this stream as well as of those previously mentioned. The silt formation is often along these valleys a striking feature, and is shown in terraces from 100 to 200 feet or more in height."

White Silts in
southern
British
Columbia.

"It is worthy of remark that on the lower part of the Okanagan Valley, as well as on the lower part of the main Thompson and Fraser, the silt is reduced in quantity and replaced by coarser arenaceous deposits, a fact tending to show the existence of rather strong current

Coarser
peripheral
deposits.

* In 1894, a series of small deltas, with steeply sloping fronts, was observed in the mouth of a valley entering the Seymour Arm of Shuswap Lake, on the west, eight miles from its head. The highest of these was estimated to be about 500 feet above the lake, or about 1650 feet above sea-level. Its existence means, that at the time the ice had almost or entirely left the lake-basins, the White Silt water still stood at the above-mentioned level.

† *Op. cit.*, p. 45-46.

action in these main outlets of the plateau region. The silt formation is entirely absent from the upper portions of the valleys occupied by Adams Lake, Shuswap Lake with its various arms, the Arrow Lakes, and the northern part at least of Kootanie Lake.*

Silts at two principal levels.

"In previous publications I have stated the maximum observed height of the main deposits of these silts of the southern part of the Interior Plateau at about 1700 feet,† but later observations show that they are developed to a notable extent at considerably greater elevations. I will here only instance the valleys of Barrière River, a tributary of the North Thompson, Upper Nicola River below Douglas Lake, and Skuh'un Creek, a tributary of the Lower Nicola, where thick deposits of White Silt, cut into terraces, were observed at heights of about 2250, 2500, and 2450 feet respectively. It is thus probable that we may place the upper level of the silt formation in this region at about 2500 feet, though it is still apparent that the more important developments of the deposit lie below 1700 feet. The silt deposits are found in this part of the Interior Plateau down to heights less than 1000 feet, but it is possible that some of the lower-level deposits have been secondarily formed from the denudation of the higher."

White Silt formation near Kamloops.

In my preliminary report on the Southern Portion of the Interior of British Columbia,‡ some details respecting the White Silt formation in the area of the Kamloops sheet are given, together with a discussion of the mode of origin of the deposit. From this source the following passage may be quoted in further explanation of the mode of appearance and character of the silts, the special reference being to one of the main developments of the formation at about the level of 1700 feet:—"In the valley of the South Thompson, the silt formation is most characteristically represented, forming as before stated, broad terraces or benches along the sides of the valley, with the surfaces gently sloping towards its axis, where the river has formed for itself a deep subsidiary channel. In some places—as above Kamloops on the south side of the valley—the edge of the White Silt bench has been cut up by little streams descending at times from its summit, into complicated and ragged ridges. The eroded faces are always very steep, and occasionally vertical, and in the sunlight have a peculiar glossy shimmer, due to the great abundance of minute particles of mica, which, when the bank is wet, become arranged parallel to its surfaces and on drying adhere in that position. The bedding is generally almost or quite hori-

*The southern portion of this lake has not yet been examined.

†Report of Progress, Geol. Surv. Can., 1877-78, p. 143 B. Quart. Journ. Geol. Soc., vol. XXXVII., p. 275.

‡Report of Progress, Geol. Surv. Can., 1877-78, pp. 142-144.

zontal and layers of a few inches in thickness succeed one another with great regularity. The deposit is remarkably fine throughout, and no boulders or stones so large as to imply the action of ice were seen. A short distance below Little Shuswap Lake, the silts appear in a bank about sixty feet above the river, but beyond this are not again met with (to the east) nor were they recognized on any part of the shore of the Great Shuswap Lake."

The occurrence of silts interbedded with gravels of local origin, in the valley of the Tranquille, has already been referred to in another connection (p. 274 B) and so has the remarkable display of interbedded silts and gravel on the Thompson some miles above Ashcroft, where such deposits form cliffs 359 feet in height (p. 274 B and Fig. 14, p. 306 B.) Similar interbedded silts and gravels are displayed near the mouth of Cherry Bluff Creek on Kamloops Lake, where cliffs, worn into columnar forms, show well stratified and rounded gravels, hard packed, for a thickness of twenty feet or more. Above these is about fifteen feet of typical White Silt, finely bedded in horizontal layers and sometimes holding flattened calcareous nodules. The White Silts are again well exposed in high bluffs or cliffs on the line of the railway following the Thompson between Black Cañon and Spatsum station.

In illustration of the coarser character of the silt deposits and the manner in which the typical development of silts dies away on the lower Thompson, the following notes are given:—The silts are seen fairly well developed about the mouth of the Nicola River and Spence's Bridge, and for a few miles beyond. But further down, below the mouth of the Nicola River and between that place and Lytton, the scarped banks in which silts might be expected to appear, show instead bedded coarse sands and gravels, with lenticular beds of pale fine sands and only occasional similar beds of silt. These finer beds are well marked and occur at a height of several hundred feet above the river a couple of miles above Lytton on the old wagon-road. They are in general horizontal or nearly so. These deposits, as a whole, appear thus gradually to replace the typical White Silts in descending the river, but it is possible that they may consist of rearranged material of somewhat later date. It is probable also, that in this narrow part of the valley, much of the material has been immediately derived from the wash from the slopes of the adjacent hills.

The discussion of the White Silt formation naturally allies itself closely with that of the terraces and shore-lines, for the body of water in which the silts were gradually laid down must, obviously, have left some such marginal traces. It is further, however, obvious that the littoral de-

Gravelly
intercalations.

Change to
sands on lower
Thompson.

Shore-lines of
water.

posits of such a body of water would probably not be silty, but rather of the nature of sand or gravel, and that the correlative terraces, whether of erosion or accumulation, cannot be expected to show in themselves, by their character, their connection with the period of formation of the silts. In endeavouring to arrive at the height held by the water at this time, it is moreover plain that the highest parts of the silt deposits are alone capable of giving definite information, as the accumulation of the silts may have gone on in some places in water of considerable depth.

Relation to
terraces.

The heights at which the silts are found, appear to render it probable that some of the lower terraces enumerated in the list already given, may actually be connected with levels held by the body of water in which the White Silts were laid down. The five last terraces of the list (Nos. 36 to 40) may particularly be suspected of standing in this relation to the White Silts, but in one case only (No. 35) is the terrace-flat itself actually formed of silt.

Special condi-
tions in
Southern
Interior.

The relative abundance of sometimes faintly impressed but yet well preserved shore-lines, at heights below that of the higher of these terraces (near to or below the upper limit of the White Silt formation), seems to accord with the date to which this formation must be assigned, which is that of the latest phenomena of the glacial period and attending its close. The circumstance, in the southern part of the Interior Plateau that the White Silts occur at or about the general upper level of the similar deposits found very widely throughout the northern Cordillera,* while at the same time their maximum development is locally confined to elevations below 1700 feet, though no such important development is noticed elsewhere at a well marked stage below the maximum level, requires explanation. It is believed to indicate a partial elevation of the corresponding portion of the Interior Plateau, during the period of deposit of the White Silts, which was local in its character and did not affect other portions of the Cordillera.†

Heights of
White Silt.

The following is an enumeration of the principal observations of the height of the upper surface of the White Silt formation, obtained in the

* Cf. Trans. Royal Soc., Can., vol. VIII, p. 49.

† It appears to be quite possible that the shore-lines lately traced in central Washington by Mr. I. C. Russell, at a horizon of about 1400 feet above sea-level, may represent a further extension (with less considerable depression) of the White Silt formation. Mr. Russell attributes these to a hypothetical "Lake Lewis," but admits that they may have been produced at sea-level in consequence of a subsidence. The suggested correlation will not hold, however, if Mr. Russell is correct in making the date of these southern shore-lines correspond with that of the maximum of glaciation. Should it be found to hold, I would still propose to employ the original designation here used for the deposits, by which their unity and synchronism throughout the northern Cordillera is implied. (See Bull. U. S. Geol. Survey, No. 108, pp. 26-27.)

southern part of the Interior Plateau. Several of these are contained in the Kamloops sheet, but for the purpose of making the evidence more complete, some are quoted from adjacent regions. These last are named in italic letters in the list:—

	Feet.
1. <i>Upper Nicola Valley</i> , between Nicola Lake and Douglas Lake.....	2500
2. Valley of Twaal Creek. White silty material flooring the valley to about.....	2500
3. Skuh'un Creek, Nicola River, bluff of White Silt, about...	2450
4. Venable Valley, near Thompson River. Silty flat, flooring the valley. Lower central part 2230 feet, sloping up to	2280
5. <i>Barrière River</i> , near the lake. White Silts seen at intervals along the valley, and may occur somewhat higher than figure.....	2250
6. <i>Grande Prairie</i> . Silty terrace, overlooking the lower plain which appears to be composed of rearranged silty material.....	2230
7. <i>Valley of Scotch Creek</i> , Shuswap Lake. Terraces of fine sandy material passing into silt and very probably connected with the White Silt formation.....	2220
8. Botane Valley. Upper and higher part of a large flat which floors the lower part of this valley. The material of this is largely silty, and like the last it apparently represents a local marginal development of the White Silts at a certain stage.....	2070
9. <i>White Valley</i> , west of Okanagan Lake. Highest observed level of silty terrace or plateau.....	2000
10. Notch through which trail leading from Spence's Bridge to Twaal Valley passes. Flat terrace-level filling valley between the hills and composed of silts.....	1890
11. <i>Valley of Deep Creek</i> , Okanagan Lake. Wide terrace-flat containing much silty material, but also sometimes sandy and occasionally stony. Supposed to represent the upper level of silt deposits about this place.....	1840
12. <i>Valley of Okanagan Lake</i> , north of Deep Creek. Terrace-flat composed of White Silt. This is the highest typical silt terrace noted along Okanagan Lake, but the deposits extend in some places down to the lake level (1150 feet). ..	1730
13. <i>Flat about summit level</i> between Salmon Arm and outlet of Great Shuswap Lake. This is crossed by the Canadian Pacific railway, and is composed to a considerable depth at least of silts, which are not so pale-coloured as usual. Average highest level.....	1708
14. General highest level of extensive silty deposits found about Kamloo, - and eastward. The edge of the deposit here appears to be marked by a beach at about 1900 feet. See p. 283 B.....	1700

It is of course impossible to exhibit in detail or describe completely the circumstances which have led me to regard the White Silts as a distinctive and important member of the glacial series. The appearance

Separation of White Silt formation from other silts.

of these deposits in the field, and their restriction, in mass, to certain levels of the country, appear to justify this view if we speak alone of the Kamloops sheet, and without reference to the wider developments of White Silts elsewhere found in British Columbia. Deposits of a silty character, however, occur in minor development, and in consequence of circumstances more or less strictly local, at various higher elevations, and thus the mere occurrence of such deposits taken without reference to other considerations, is not diagnostic.

Silts of Highland Valley.

The only occurrence of silts in mass and forming entire, though low, terraces distinctly above the general maximum level, in the area of the Kamloops sheet, is one met with in the Highland Valley. The silts developed at this place are quite local, and appear in that part of the valley which drains north-westward to the Thompson River, at a level somewhat less than 4000 feet above the sea. Small moraines are also found in this valley, of such a character as to show that a tongue of ice occupied it and pushed south-eastward in it at one stage in the decline of the general Cordilleran glacier. It is supposed that a glacier-lake was here formed between the front of the ice-tongue and the watershed in the valley, in which a certain development of silts took place before it was drained (p. 301 B).

Silts of Louis Creek Valley.

The upper valley of Louis Creek, a short distance beyond the Kamloops sheet to the eastward, apparently affords another case similar to the last and explicable in the same way, which may be briefly referred to because of its bearing on the general question. This deep valley again slopes in a northerly direction, the stream rising only a short distance from the north bank of the South Thompson, from which river the valley may be entered by a somewhat remarkable notch in the plateau. In the upper part of the Louis Creek valley, rather important and well marked silty terraces, through the material of which a certain amount of angular rock-débris is scattered, reach up to 3460 feet. This is approximately the height of the notch above referred to, and there is every appearance to show that through this notch a large stream at one time flowed. This could only have occurred when a tongue of the retreating glacier still filled the lower and northern part of the Louis Creek valley, precluding the northward flow of the water, and producing a glacier-lake in which the silts are supposed here to have been locally deposited.

A glacier lake.

Similar occurrence on Hat Creek.

While speaking of such local glacier-lakes, it may be mentioned that it appears to be probable that still another of a similar kind was at one time produced in the same way at the head of the Hat Creek valley. A considerable stream draining this temporary lake seems to

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have flowed out by way of Jack's Creek to the Bonaparte, and to have been largely instrumental in giving its present appearance to the Limestone Amphitheatre on Jack's Creek. No remarkable development of silty deposits was, however, noted in this place.

If such local occurrences of silts at high levels as those just alluded to, be referred to the period of the retreat of the main glacier, it will be observed that they must antedate the main White Silt formation, previously described. It may also be noted in passing, that the elevations at which the waters of the glacier-lakes of Louis Creek and Hat Creek valleys flowed out into different parts of the Thompson Valley, show that any general flooding of the country which may have followed the retreating ice-sheet, can not, at the times of existence of these lakes have progressed to a greater height than that of their outflows, or about 3460 and 3900 feet respectively. Date of these lakes.

It is of course possible, that such glacial lakes may have been produced by glaciers of a relatively local character during the maximum of the second period of glaciation, and if so that the silts of Highland Valley and Louis Creek valley may be contemporaneous or nearly so with those of the main deposit.

A reference to an earlier page of this part of the Report (p. 252 B) will sufficiently indicate the mode in which the White Silt formation is supposed to have been produced, and the relative position which it is believed to hold in the sequence of events of the glacial period.

Drumlin-like Ridges.

Within a certain area of the Kamloops map-sheet, as well as for some distance beyond its south-eastern limit, ridges more or less closely akin to true drumlins occur in considerable abundance. I am unable to assign a precise place to these in the scale of events of the glacial period. Attention was not specially directed to them till 1890, and the evidence respecting them is still in many respects incomplete.

The principal development of these drift-ridges is found in a belt of country to the south of Kamloops, extending in width from Cherry Bluff and Alkali creeks to the eastern edge of the map. From the latitude of Kamloops, this belt runs south-eastward, including the Stump Lake valley and the adjacent parts of the plateau on both sides, with the vicinity of Douglas Lake, and Chaperon Lake east of the edge of the map. To the northward of Kamloops no similar phenomena have been found, nor were they observed to the south of Area characterized by drift-ridges.

the lakes last mentioned, although the country in that direction has not yet been very closely examined.

Character and
elevation.

Within the area thus defined, the ridges have been found in great numbers between elevations of about 2500 and 3500 feet, although these heights are not stated as strictly limiting ones. The ridges take the form of long pencil-like accumulations of drift material, generally, but not always, sheltered behind and dependent on rocky projections. So far as observed, they point south-eastward or southward, in directions corresponding closely, in each case, with those indicated by the striation as that of the motion of the Cordilleran glacier. Superficially they consist of gravel and earthy material with small boulders, and although no satisfactory sections have been observed, they are at least in part composed of boulder-clay.

Localities
where
observed.

Drumlin-like ridges of the kind referred to, may be seen well developed in the wide valley of Alkali Creek, in the vicinity of the upper part of Peterson Creek and on the low plateau about Separation Lake. They are generally arranged in parallel series, and when viewed at right angles to their length simulate terraces, their crests often running nearly horizontally for a quarter or half a mile, but always eventually sloping down to the southward, and, where not manifestly dependent on rocky masses, declining in the same way to the northward. They are very well shown in the entire wide valley of which Stump Lake occupies the lowest part, occurring at all heights, from the lake-level (2450 feet) to the summit of a conspicuous hill which stands nearly isolated to the north-west of the lake, with an elevation of about 3600 feet. A sketch of the upper part of this hill is here given, and is of particular interest in showing two or three delicately impressed, but still quite distinct, horizontal terrace-lines, marked upon the surface of the drift material which has accumulated behind the rocky crag.



FIG. 11. SKETCH OF UPPER PART OF HILL NEAR STUMP LAKE.

Showing drift-ridge in lee of crag, marked with faint terraces.

North of the Upper Nicola Valley (above Nicola Lake) similar drift-ridges were observed at a height of about 3000 feet, with a south-easterly direction, as though the agent producing them had been diverted toward the less elevated country to the east of the Meander Hills. To the north of Douglas Lake, they were found at a nearly

corresponding height, running about S. 25° E., and to the west of Chaperon Lake to a height of about 3500 feet, with directions varying from S. 25° E. to south.

The only other part of the area of the Kamloops map-sheet in which such drift-ridges were noted, is on a portion of the plateau to the south of the lower part of Meadow Creek, and between that creek and Guichon Creek. Here the terrace numbered 12 in the list on page 278 B occurs. Rocky prominences standing above it, show long attached tails of drift pointing about S. 50° E., and the surface of the terrace itself is grooved by long hollows parallel in direction, evidently due to the same cause with the ridges, acting at the same time. The terrace mentioned here is at an elevation of 4400 feet, and as the ridges somewhat exceed this, they are the highest instances of the structure in question which have been found.

Ridges contemporaneous with water action.

In this case it is pretty clear that the drumlin-like ridges and the terrace must either be contemporaneous, or that the terrace is the older. In that of the hill near Stump Lake, the terrace-markings must have been produced either at the same time with the drift tail or at a later date. In both the occurrence of water action in close relation to the ridges is apparent.

Respecting the physical features of the region first described, and that in which the main development of such drumlin-like ridges occurs, it may be explained that, apart from the narrow valley of the Fraser, it forms one of the principal southern outlets of the Interior Plateau of the province. From this it may be argued, that the circumstances attending the flow of the Cordilleran glacier along this wide depression, were those which gave rise to the ridges, in the manner ordinarily assumed for the formation of drumlins. But the Okanagan Valley, to the eastward, formed a second and at least equally important avenue for the escape of the glacier-ice from the plateau, and in this vicinity, although the circumstances appear to be equally favourable to their production, no similar well-marked ridges are found, and if they occur at all (of which I could not satisfy myself,) they are inconspicuous and insignificant.

Physical features of region of drift ridges

Drift-ridges of this character are therefore not a general normal result of glaciation in the region, but are due to some exceptional and relatively local cause, and the fact that they characterize chiefly a wide depressed area in the plateau country, through which the ice is known to have passed in their direction, is not in itself sufficient to show that they have been produced by the passage of such ice; for the same physical features would equally have given a similar direction to

Such ridges exceptional.

any body of water seeking an outlet, and the existence of high terraces throughout the country, shows that it was deeply flooded during a part or parts of the glacial period.

Probable date
of formation
of ridges.

Although not in a position to arrive at any definite conclusions regarding the mode or date of origin of these drumlin-like forms, it may be useful to enumerate the main points which bear upon these questions, before leaving the subject.

They almost certainly antedate the White Silt formation, which is attributed to the latter part of the second epoch of glaciation. There is no reason to believe that either ice or water reached such high levels at or after that time, and, moreover, the White Silts themselves could scarcely have remained under the stress of circumstances such as to account for the production of the drift-ridges.

Their mode of
origin.

This being admitted, it must be supposed that they originated either as a direct result of the passage over the country of the main Cordilleran glacier, or in consequence of circumstances immediately succeeding that event. They may thus have been formed:—(1) Beneath the mass of the great glacier in the manner usually attributed to drumlins. (2) Along the margin of the retreating ice either sub-aerially or below water. (3) By some exceptional and sudden movement of a great volume of water about the close of the time of maximum glaciation.

Against the first hypothesis is the exceptional character of the drift-ridges relatively to the whole area examined, and the freshness of their forms. Had their date been so early, they could scarcely have escaped much denudation and extensive burial during the submergence evidenced by the numerous high-level terraces. They must have been exposed successively at every level to the waves of the declining edge of the water, having already been subjected to the denuding action of the water flowing from the edge of the retreating glacier itself, whether on land or in a body of water.

Under the second hypothesis, it is easy to imagine that tunnel-like cavities may have been produced from time to time by the protrusion of the edge of the glacier over masses of rock, in which deposits resembling the drift-ridges might have been formed. But such cavities should be flaring outward, a form not followed by the deposits in question, and the effects of issuing waters, already alluded to, should be equally manifest in this case.

The third hypothesis, assumes that the ridges were produced partly by denudation and partly by accumulation, along the path of some

great and relatively sudden outflow of water. There is much evidence of denudation in the same region, afforded by the hollows of numerous small lakes. Such a local flood as that assumed by this theory, might occur either by the bursting of the icy borders of an englacial lake, like that already spoken of in connection with the origin of the higher terraces, or by a general outflow from the Interior Plateau consequent on some rather sudden movement in elevation of the land about the close of the first and greatest epoch of glaciation.

Moraines.

If the last-described hypothesis of the formation of the drift-ridges be correct, most of the moraines met with must be older than these. Some are certainly older than many at least of the terraces, others show evidence of contemporaneity with certain terraces, while a few appear to be relatively of quite recent date. As it is impossible to treat of the various phenomena of the glacial period strictly in their order of sequence, from doubt which exists as to this precise order, and from the overlapping in time of the various events, it has been decided to give a few notes on the moraines collectively in this place.

Moraines of different classes.

Within the area of the Kamloops sheet, very numerous observations have been made on moraines. A considerable proportion of these are pretty evidently due to stages in the diminution of the Cordilleran glacier. In other cases, moraines appear to have been formed locally by the movements of subordinate masses of ice which becomes detached from the main glacier, and for a time remained, capping plateaux or other elevations; assuming a proper motion due in each case to the actual slopes of the country upon which they lay. Others, again, may with probability be assigned to the second though less severe maximum of glaciation, while in the mountains of the eastern margin of the Coast Ranges, a small increase of the present snowfall would reproduce the local glaciers to which some of the moraines there may be attributed. One of the more important features directly due to moraines, is the formation of many of the lakes with which the map is strewn. Moraine-dams hold in a large number of these lakes.

As the Cordilleran glacier gradually diminished, its front appears to have become very irregular in outline, and tongues or lobes seem to have occupied certain main depressions after the adjacent higher regions had often become free from ice. The moraines which occur in such valleys and which appear to have been produced in this way are always small, though often well marked. Their small size seems to show that

Retreat of Cordilleran glacier.

the glacier retreated pretty rapidly, and though it may have occasionally re-advanced, did not long remain at any one place. The material composing these moraines, so far as it has been examined, resembles that of the boulder-clay, but is often more gravelly in composition and contains a larger number of rounded stones. No really typical moraines, composed of large angular or sub-angular blocks, such as those which occur along the eastern base of the Rocky Mountains in connection with the old local glaciers of that vicinity, are met with in this region, except possibly in the Coast Ranges.

Moraine due to this time.

Some miles beyond the southern edge of the Kamloops sheet, south of Nicola Lake and a few miles south of Lac à la Fourche, in an important valley which leads southwards toward the Similkameen, transverse moraines, evidently formed by ice pressing onward from the north, are found at an elevation of 3620 feet. In another valley which branches westward from Lac à la Fourche, moraines indicating a westward motion of ice occur at about 3830 feet, and it is evident that here, a subordinate tongue of the main lobe sought exit in that direction, at one stage in the retreat.

The next clear instances of this kind, little complicated with other phenomena, and due to a later stage in the withdrawal of the glacier-front, are met with near the lower part of the valley of the North Thompson, a few miles north from Kamloops. It is evident that an important lobe occupied the North Thompson valley, and that it spread at one time over the lower hilly tract named the Garde Lafferty. As it shrank back from this tract it left small moraines, one of which may be traced for a considerable distance across the undulating hilly country of the north-eastern part of the Garde Lafferty, as a well-defined low earthwork-like ridge. On the opposite side, this lobe, or a part of it, occupied the Inner Valley of the map, and the valley of the upper part of the north branch of Reservation Creek. Moraines were here observed at heights of 2400 and 2600 feet. A branch of the glacier seems also to have pushed eastward in the valley of Edwards Creek, and about the lake of the same name (a short distance beyond the east edge of the sheet), where moraines are numerous at a height of about 3200 feet.

Probable glacier lake.

The moraines in the valley of the north branch of Reservation Creek, are partly terraced by water action. Near Edwards Lake, terraces occur above the moraines, at a height of about 3500 feet, and it appears to be quite probable that a lobe from the Inner Valley here moved eastward, while one from the upper valley of Louis Creek (see p. 290B), pushed in an opposite direction, and that

the moraines and terraces are due to these and to the small glacier-lake which may for a time have been produced between them.

Near the north-western part of the Kamloops sheet, the slopes of the Green Timber plateau, in the vicinity of Clinton, are covered by a confused mass of morainic material, rising nearly from the level of the wide valley in which Clinton is situated (3040 feet) for several hundred feet above it.

The occurrence of large quantities of basalt boulders, which have evidently been derived from the Green Timber plateau, in the part of this valley which runs toward Kelley Lake, doubtless indicates that a lobe of the northern ice for a time pushed in this direction, following the low ground.

The Green Timber plateau itself, was probably the last part of the Kamloops sheet which was connectedly covered by the diminishing mass of the Cordilleran Glacier. The occurrence of moraines in association with terraces, where this plateau is bounded to the westward by the southern part of the Marble Mountains, has already been referred to (p. 268 B). The moraines here are at a height of about 5500 feet above the sea-level. They may be regarded as lateral moraines, and their height seems to imply that at the date of these formations the surface of the glacier stood about 2000 feet above the lower part of the Green Timber plateau, to the north-eastward. Near the northern part of the same base of the Marble Mountains, moraines and terraces are again associated. These are alluded to on pp. 268 B, 278 B. The two principal levels of moraines noted here, are, near Big Bar Lake, 3730 feet, and again at a height of 4300 feet, and the connection of the moraines and terraces is believed to imply a couple of short re-advances of the glacier, by which the general progress of its recession has been interrupted.

The general surface of the Green Timber plateau is also characterized by numerous moraine-ridges and by some ridges which may represent kames or eskers. A number of these have been noted in traversing the plateau, but no systematic survey of the whole has been made, though such a survey would probably bring out points of interest. These ridges are generally about fifty feet in height and seldom exceed one hundred feet. Between Big Bar Lake and the wagon-road to the south-east, they were noted particularly at heights of about 4150 and 3900 feet. They are associated with sandy terrace-flats, but are themselves often sharp and unaltered. Further east on the plateau, to the north of Fly Creek and between that stream and Green Lake (north of the edge of the map) similar moraines are again well developed, and the

Moraines near Clinton.

Moraines and terraces on Marble Mountains.

Green Timber Plateau.

old Brigade trail follows some of them for miles. These were found to be flattened off by water action at levels between 3790 and 3890 feet, but above the last-mentioned level, did not in this place show any distinct evidence of terracing.

In the foregoing paragraphs, it has been endeavoured to notice some of the moraines which more distinctly evidence the several positions of the retreating front of the Cordilleran glacier, but in so doing the connection of many of the moraines with contemporaneous or very shortly subsequent terracing has necessarily been alluded to. Other marked instances of this association of moraines with terraces may be noted as follows.

Association of moraines with terraces, Guichon Creek.

In the wide though rather high depression which, running from north to south, forms the valley of Guichon Creek, there is a remarkable association of moraines and terraces which must be assigned a proximately contemporaneous origin. Moraines are everywhere abundant on the upper part of Guichon Creek to the west of Toonkwa Lake, as well as to the east and south-east of that lake. In the last-named locality they tend to run north-and-south, and appear to be lateral moraines of a tongue or lobe. All these are at levels approximating to 4000 feet and show only occasionally some traces of water action. Further down in the Guichon Creek valley to the north of Witches Brook, at a level of about 3500 feet, flat-topped moraine-ridges abound, both parallel to the sides of the valley and more or less directly transverse to it. Some of these have held in ponds, which have now for the most part been drained. On the west side of the valley, below Witches Brook, similar closely connected moraines and terraces occur at nearly the same height as before, and lateral moraines are very well marked in places on the opposite side of the valley. Again, on the west side of this valley and extending from a point about two miles below Mamit Lake southward for several miles, a remarkable display of rough, irregular moraine-ridges is found. Some of these are nearly transverse to the valley, others, particularly those nearest the present stream, in the bottom of the valley, run nearly parallel with it, but little general regularity in trend is apparent. The moraine-ridges are here full of granite blocks and boulders, and are so closely crowded together that they are often separated only by narrow V-shaped valleys. As noted elsewhere, (p. 279 B) terraces appear on the slopes of this part of the valley high above these moraines, which may be stated to occur at levels of 3300 to 3200 feet. Among the moraines, terraces formed of their material also appear, and in following the valley for a couple of miles further, the terraces become the more prominent feature, but still show, by the occasional pot-holes

which indent them, their superposition on moraine material. On the summit of the plateau, some miles to the west of this part of Guichon Creek, about the watershed between it and the main Nicola River, at heights of 4300 to 4400 feet, moraines and terraces are again found so closely associated as to suggest contemporaneity, but these belong to a different and probably earlier stage, and are possibly due to different conditions from those which have just been described.

Reverting to the moraines and terraces of the lower part of Guichon Creek, it is interesting to note (though in doing so reference must be made to a tract of country somewhat beyond the south edge of the map) how frequent the association of moraines and terraces is at a level approximately identical. In different places along the Coldwater Valley and following the Voght Valley to the sources of Otter River, extending thus about thirty-five miles southward from the locality particularly referred to as Guichon Creek, terraces were noted, in ascending, to be replaced by moraines at levels of 3310, 3220, 3230, 3260 and 3290 feet approximately. Taking into account the somewhat indeterminate character of the phenomenon and possible errors of observation in height, the facts seem to prove that water stood for some little time in this region at about the elevation indicated. A comparison of the circumstances here, with the generally higher levels of similar instances to the northward, suggests that an increasing depth of water followed the retreating edge of the Cordilleran glacier.*

Other instances of moraines and terraces.

The following are a few additional instances of places in which moraines were noted to have a considerable development, but in which they did not show any distinct relation to terraces. Some of these moraines may be due to ice moving from the higher parts of the region at dates subsequent to that of the main glaciation, while others are pretty certainly the result of the Cordilleran glacier itself in its waning stages.

Further examples of moraines.

Upper part of Moore Creek, to south-east of Trout Lake, numerous moraine-ridges, often parallel to the valley. Elevation about 3500 feet.

Meadow Creek valley—This contains numerous hillocks and transverse ridges, evidently representing moraines, but partly buried in horizontal deposits which have formed in ponds and marshes between them. Elevation about 4000 feet.

Murray Creek valley—Numerous moraine-ridges occur in the wide part of the valley, where a tributary stream enters, at an elevation of about 3790 feet. Terraces are found about fifty feet lower.

Blue-earth Creek, a tributary of Hat Creek—In the lower part of the valley of this stream, transverse, gravelly, moraine-ridges occur at a level of about 4550 feet and somewhat lower. These appear to have been formed by an offshoot of the tongue of glacier-ice which at one time pushed southward along the upper valley of Hat Creek.

Medicine Creek, also a tributary of Hat Creek—Moraines occur in the lower part of this valley between about 3500 and 4000 feet. They have probably been produced in the same way with those last noted.

Vicinity of McLean Lake, between Ashcroft and Hat Creek—Very distinct moraine-ridges occur to the south of this lake, on the slopes of the hill, with easterly and westerly trends and deep narrow intervening valleys. Elevation about 4000 feet. Cattle Valley, running north from McLean Lake, is also in its southern part encumbered and often ridged across by moraines. All these moraines seem to have been formed by a tongue of ice pushing southward along the Cattle Valley.

Upper valley of Pavilion Creek, where it runs through the higher parts of the Pavilion Mountains—Much earthy drift in this part of the valley, apparently arranged in the form of moraines formed by an offshoot of ice pushing eastward.

Valley connecting Copper Creek with Criss Creek. Near the lakes in its northern part, at heights somewhat greater than 3000 feet, numerous small moraines, both longitudinal and transverse.

Moraines
damming
lakes.

Moraines directly concerned in the formation of lakes have not been enumerated in the foregoing pages. They do not of course differ in any essential respect from many of the others, but it has been thought best to note a few conspicuous instances of these together. Already several cases have been alluded to of ponds and lakelets held in by moraines but since emptied by the cutting down of their issuing streams. There are also almost innumerable cases of small ponds which lie in pot-holes in morainic country, or between moraine-ridges, which have not been considered to be worthy of separate note.

Instances.

Trout Lake, at the head of Meadow Creek, (4100 feet) is evidently held in by more or less degraded moraines. Fish Lake and Big Fish Lake on Greenstone Creek are similarly moraine-dammed at elevations of 4840 to 4100 feet. The moraines closing the first are more or less degraded by weathering or water action, but in the second case they are well preserved. These moraines are in part transverse to the valley but also in part parallel to it, and it is not possible to state whether they were produced by a tongue of the Cordilleran glacier or by local glaciers moving down from the adjacent plateaux. A small lake or

pond south of the middle part of Meadow Creek, not named on the map, is surrounded by moraine ridges. It here seems probable that a local glacier, descending from the eastward, may account for the moraines and for the preservation of the basin of this little lake. The lakes of the Highland Valley, with heights of about 3900 feet, are also moraine-dammed. As previously stated (p. 290 B) it appears that the ice forming these moraines came from the westward. The lakes in the northern part of Glen Hart valley, again lie between moraines which have been thrown down in the valley. Though not certain, it appeared to be probable that the ice forming these was a local tongue which for a time moved northward in the valley, towards Clinton. The small lakes in the southern part of this valley seem to be caused by fans which have locally interrupted the drainage. On the Green Timber plateau it has already been noted that lakes inclosed between moraines are common. The numerous lakes about Skoatl Point, are not evidently due to moraines, but appear rather to owe their existence to material of the character of boulder-clay, irregularly distributed over a previously uneven rocky floor.

The foregoing notes on moraines in general are not entirely satisfactory, because it is impossible to discuss individual cases at such length as to render manifest the bearing of the local topography on their existence or position. They may suffice, however, to show how commonly moraines are met with in the region covered by the Kamloops sheet, which may be taken as a specimen of much of the Interior Plateau of British Columbia. One fact is so striking as to deserve special mention, *i. e.* that no very large moraines have been found. The moraine-ridges seldom attain a height of one hundred feet above their bases and are often not fifty feet in height. It is further notable, that large boulders occur only exceptionally and locally in them, while much of their material appears essentially to resemble that of the boulder-clay, or, where it shows points of difference, these tend to evidence greater water action and more rounding of the contained stony material. All the circumstances seem to show that, though the ice occasionally ceased its retreat and even advanced again for a certain distance, the main movement in retreat was rather rapid, and most of the material thrown into the form of moraines when a halt occurred, or a temporary re-advance happened, was that which otherwise would have gone to form ordinary boulder-clay, or which had already been deposited in that form and was subsequently ploughed up.

It is further remarkable, that no moraines have been recognized in this area below a level of about 3000 feet above the sea, or in other

General remarks on moraines.

None large.

None at low levels.

words, that none of the lower and larger valleys are characterized by moraines. Various explanations may be suggested to account for this circumstance. It may be supposed, for instance, that such moraines as were produced in these lower valleys were subsequently destroyed during the period of denudation which appears to have followed the main glaciation. (See pp. 251 B, 271 B). It may again be suggested, that the considerable depth of subaqueous deposits which occurred in these lower valleys covered and masked the moraines, or such remnants as were left of them. It is believed that both these causes may have coöperated, but in the present state of our knowledge it is not deemed advisable to discuss the matter further.

Absent from
vicinity of
drift-ridges.

In conclusion, still another point may be remarked on. This is the relative, or possibly nearly complete, absence of recognizable moraines in the belt of country which is principally characterized by the occurrence of the peculiar drift-ridges which have been described in a preceding part of this portion of the report (p. 291 B). This statement applies principally to the notable valley which runs southward from Kamloops. As no satisfactory reason can be given to explain the original absence or paucity of moraines in this particular valley, it becomes reasonable to suggest that the special conditions which have produced the ridges have removed, or have so changed as to obscure, the older moraines. If it be admitted that the ridges resulted from a rush of flood-water at one particular stage of the glacial period, it is easily conceivable that such moraines as may have remained, resulting from the antecedent retreat of the Cordilleran glacier, may have lost their identity at this time and in the area so affected.

GLACIAL AND POST-GLACIAL HISTORY OF THE FRASER AND THOMPSON VALLEYS.

Valleys excavated during the Pliocene.

The excavation of the great valleys now occupied by the Fraser and Thompson rivers, is believed to have been accomplished wholly or almost wholly in the interval between the close of the Miocene Tertiary and the beginning of the glacial period. Many observed facts show the post-Miocene age of these valleys, but perhaps the most striking is the occurrence near Leon and Pavilion creeks and again about Big Bar Creek (the last-named situated a short distance beyond the edge of the Kamloops sheet) of horizontal basalts and sandstones referable to the Miocene, on both sides of the valley but now cut through and fringing, far up, the edges of the plateau. Such excavation as may have occurred in these valleys during or after the glacial period, is, in fact, quite insignificant, compared to the pre-glacial erosion. It

is nevertheless a matter of some interest, particularly in its intimate connection with the problems offered by the occurrence of alluvial gold along these rivers.

As already noted, there can be little doubt that both these great valleys were throughout more or less deeply filled with boulder-clay, or analogous drift deposits, at the close of the first maximum of glaciation. This epoch is supposed to have been followed by a subsidence, during which, not only these valleys but much of the adjacent plateau country was deeply flooded, and this again is believed to have been succeeded by a reelevation, that was either a forerunner of or coincided with the earlier stages of a second less severe and more local glaciation. The evidence relied on to show that the Fraser and Thompson valleys were during this time of elevation practically cleared of the boulder-clay deposits which had previously encumbered them, is referred to on page 271 B. On another page of this Report (p. 275 B) certain remarkable cones of dejection, composed chiefly of boulders and formed opposite the mouths of some streams which enter the Fraser and Thompson valleys, are described, and it is explained that these probably had their origin after the removal of the greater part of the boulder-clay, and during the earlier portion of a still later period of flooding of the valleys, before the close of which the White Silt formation was produced.

Summary of
glacial history.

It is difficult, in the presence of so many interlocking phenomena, to arrive at certainty as to the precise nature of the train of events, but that here sketched now appears to me to be the most probable one, and is referred to, with reserve, as a basis of arrangement for our ideas in respect to the later history of these great valleys.

In addition to the rough cones of dejection above alluded to, which were evidently formed only where there was an adequate supply of large boulders and occasional heavy local floods sufficient to transport these, many "fans" occur along these valleys opposite the mouths of streams. These are with probability assigned to the same period. In my Preliminary Report on the Southern Portion of the Interior of British Columbia (1877) I have named the accumulations here referred to "fans" (p. 10 B) following Drew* and no better descriptive name can probably be suggested for them.

Nature of
"fans."

Fans may be formed at the opening of a narrow valley upon a plain or wider valley either below water, as of a lake, or sub-aerially. In the former case, their slope from the mouth of the tributary valley, is generally low,

How produced.

*Quart. Journ. Geol. Soc., vol. XXIX., p. 441.

their material is usually pretty well stratified, and under certain circumstances they become nearly flat-topped and pass into ordinary delta-plains. When formed sub-aërially, they are built up somewhat more irregularly, by the lateral deposition of débris by the stream itself, which continually changes its course to those parts of the fan which are lowest or least blocked by previously deposited matter. Fans are thus, in another direction, connected with cones of dejection, from which they differ essentially only in the greater fineness of their material. Fans of both kinds described above, are very common throughout the southern interior of British Columbia, but those to which particular attention is here drawn, in the Fraser and Thompson valleys, have evidently been produced at a time when these valleys were flooded. This is shown, first by the nature and arrangement of their materials, second by the fact that some of them have been able to spread completely across the valleys, which they could never have done while a large and rapid river occupied the valley.

Fans older
than river-
terraces.

The larger fans, of which there are many along the Fraser and Thompson valleys, have evidently been produced at a time previous to that of the formation of the river-terraces, which took place during the post-glacial period, for these terraces are cut out in the material with which the valleys were partially refilled after the removal of the boulder-clay and previous to and during the time of the White Silt formation. As instances of these older and more important fans, those of La-loo-wissin Creek, another stream two miles above this, and Cinquefoil Creek may be referred to. There is also a wide fan of this character at the mouth of Deadman River, to which the damming back of the water of Kamloops Lake is evidently largely due. Even the fan at the mouth of Hoey Creek, at Lillooet, though a small one, is cut away into terraces below and only its upper part remains intact.

Later addi-
tions to fans.

There are of course many smaller fans of later date than the terraces and of sub-aërial origin. These are often spread out upon the surfaces of some of the terraces, and doubtless the construction of fans has never entirely ceased since the beginning of the older ones and is still to some extent in progress. Many of the older fans have also, at later dates, received superficial additions sub-aërially. A good instance of this is seen at Eleven-mile Creek, two miles above Fountain Creek, where the stratified gravels and sands of an old and evidently sub-aqueous fan, are irregularly covered by a rough wash much resembling boulder-clay, but distinctly a deposit brought down by the stream. At a still later date, and in consequence of the lowering of the river-bed into which the stream discharges, the stream has cut a ravine through both

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deposits. This subsequent trenching of the old fans is another feature common to most, or all of them.



FIG. 12.—SECTIONAL DIAGRAM OF A FAN PROJECTED ACROSS THE WIDE RIVER VALLEY, DURING A PERIOD OF SUBMERGENCE.

a. Position of former river-bed.



FIG. 13.—SECTIONAL DIAGRAM, SHOWING NEW CONDITIONS ON REËLEVATION.

a. Position of former river-bed.

b. New river-bed, forced against the rocky wall of the valley, and cutting terraces in the old fan.

Where the larger old fans have been projected quite across the river- Effect on
valley, the river, on resuming its course when the flooded state of the course of river.
valley ceased, has selected the lowest point, and is therefore usually found to be pressed close to the side of the valley opposite to that on which the stream producing the fan enters. Here it has very often cut out part of its new bed in the rocks of the side of the valley, and in a few cases has cut a new channel largely in the rock and has thus formed a little cañon.

These old fans are of course only special cases in the general process Connection
of the filling of the Fraser and Thompson valleys with drift materials, with valley-
which ensued on their flooding and continued doubtless during the filling gener-
entire period of the formation of the White Silts. The materials with ally.
which the valleys were thus partially filled, consist of stratified gravels, sands and silts, evidencing no doubt, more or less current action, but such as may have effected a body of water with a large sectional area, and very different from any deposits of the present rivers. The silts are in certain places largely developed, and in some instances are very closely connected with, if they do not actually form a part of the fans. The principal localities in which the silty deposits are shown have already been referred to (p. 283 B).

Valleys at
close of sub-
mergence.

During the subsidence of the waters in which the White Silts were laid down so widely in this part of the province, it is probable that a certain amount of erosion of a general character occurred, in these main valleys of outflow, before the water became actually concentrated into true river-channels. In any case, as a result of this period, the valleys were left, about the time that true river conditions resumed, deeply floored with drift deposits, in which during the post-glacial and modern period, with the country standing at or about its present elevation relatively to the sea, the Fraser and Thompson have re-excavated their comparatively narrow actual channels, producing series of river-terraces as they cut down.

Depth of post-
glacial excava-
tion.

The depth of this post-glacial erosion varies considerably in different places, but can generally be approximately determined, by producing the light slopes of the remaining portions of the old floor, which can often be recognized, till these meet in the axis of the valley. Notes made in this manner, show that the Fraser Valley, near the mouth of Cinquefoil Creek and thence to Lillooet, was filled to a depth of 350 to 550 feet above the present water-level. From Lillooet to Pavilion Creek, the depth of filling appears to have averaged about 400 feet, while above Pavilion Creek it becomes rather deeper, and near the place at which the Fraser enters the Kamloops sheet, it appears to have been as much as 600 to 800 feet. On the Thompson River near Ashcroft, the surface of the drift deposits filling the valley stood at least 300 feet, and possibly as much as 500 feet, above the present river-level.



FIG. 14.—SECTION OF EAST SIDE OF THOMPSON RIVER, ABOVE THE BONAPARTE.

Illustrating the post-glacial re-excavation of the Thompson Valley in later-glacial or interglacial deposits of the White Silt period. (See p. 325 B).

- a. Stratified sands and gravels, often false-bedded, about 30 feet.
- b. White Silts, in vertical bluffs, about 35 feet.
- c. Stratified gravels, about 30 feet.
- d. Re-deposited silts and gravels, filling post-glacial river-bed, 15 to 20 feet.

The lower line of the section is at the railway track, about 40 feet above the river. The bank below the railway appears to consist chiefly of stratified gravels, but is imperfectly exposed.

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FRASER RIVER, NEAR FOUNTAIN.
Showing Terraces and depth of post-glacial Erosion.

G. M. DAWSON.—Photo. Sept. 16, 1889.

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The figures just given afford an approximate measure of the depth of the post-glacial erosion accomplished by the Fraser and Thompson, but this cutting-down was probably carried on pretty rapidly at first, and afterwards more slowly, as the river began to transgress on the rocky sides of the valley, or to reach its old rocky bed. The general result of an examination of the Fraser and Thompson rivers, so far as these are included in the map, from this latter point of view, seems to prove, that where the old rocky bed has been deepened at all, this has been to a very inconsiderable amount. Near the southern edge of the map and beyond it, the Fraser appears to have cut somewhat deeper than the bottom of the pre-glacial valley. Further up, above Lytton and between Cinquefoil Creek and Lillooet, it can scarcely have reached its old bed, for though in some places bordered by solid rock on both sides, the gravelly material of the terraces, often for considerable distances, descends to and apparently below the level of the water. Thus, where rock shows on both banks, the river must be supposed to have cut its new channel across projecting points. From Lillooet Bridge to Fountain Creek, however, the river is very generally bordered by rocks on both sides, in such a way as to show that it has probably accomplished some little erosion in the rock itself. It has certainly done so in the east-and-west portion of this part of its course, for some miles below Fountain Creek, where very steep rocky walls rise to a height of 100 to 300 feet above the water. The valley is here narrow and cañon-like and the new course of the river must coincide with the old, the former channel having been again cleared out between the same rocky walls.

Relation of modern rivers to 'bed-rock.'

FRASER north to Fountain.

For some distance above Fountain Creek, the river seems scarcely to have yet regained its old level, but above Pavilion Creek, the quantity and manner of appearing of the rock along its margins, leads to the belief that it has reached its old level or has even cut down somewhat lower than it. There are also in this part of the river, several little rocky cañons, which evidently show where the river has taken a new course in the wide trough-like valley and has cut across points of rock in so doing (p. 327 B).

Above Fountain.

Reverting to the east-and-west part of the river below Fountain Creek, it may be added that the conditions met with there, appear to be such as to indicate a slight differential uplift of this part of its bed, which may have taken place along the axis of the ridge of Cretaceous rocks which crosses the river. It is, moreover, notable that no low river-flats of considerable size occur along the river for a considerable distance above this place, the new trench now occupied by the river, being cut through nearly the whole depth of the glacial filling. This may indi-

Peculiar conditions near Fountain.

Thompson
River.

cate that it required a long time for the river to completely clear out the filling of the cañon-like portion below Fountain Creek. It cannot be supposed that any possible differential uplift was sufficient in amount to account for this particular feature. It certainly seems, however, that this cañon-like part of the river has been one of the latest to be fully excavated in pre-glacial times, and that a waterfall may have long existed here. That part of the Thompson above Lytton which lies in an east-and-west bearing, has a like, new, narrow and raw character, and appears to require a similar explanation. For the Thompson River generally, above the part just referred to, the evidence is not perfectly conclusive, but appears to point to the fact that it now flows little if at all below its pre-glacial level.

It is certain, on the other hand, that the North Thompson, for at least twenty-five miles above Kamloops, and the South Thompson throughout its length, or to the point at which it issues from the Shuswap lakes, have not anywhere cut down to the level of their pre-glacial beds; nor is the fall on these lengths of river, governed by the level of Kamloops Lake, at present sufficient to enable them to accomplish any appreciable amount of excavation.

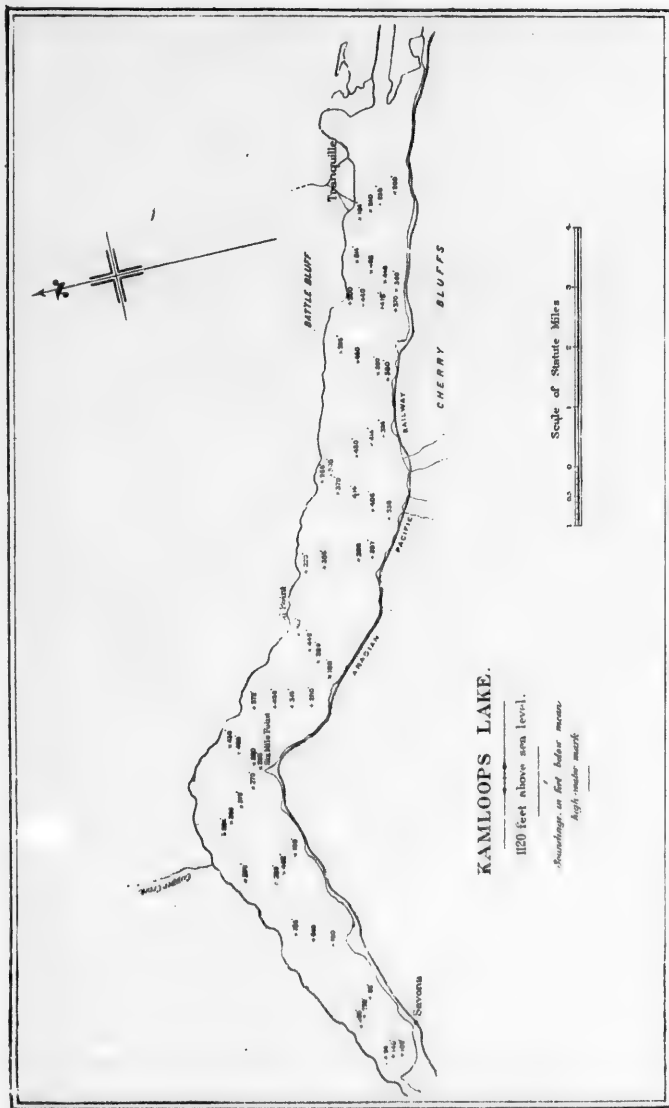
KAMLOOPS, NICOLA AND BONAPARTE LAKES.

Depth of
Kamloops
Lake.

A certain part of the valley of the Thompson is occupied by Kamloops Lake, eighteen miles in length, and if the history of the later Tertiary erosion is correctly given on page 318 B, the trough now occupied by the lake must have originated in the later Pliocene. Some soundings were made in this lake by myself in 1877, but in 1894 Mr. McEvoy carried out a number of soundings in all parts of its extent. The greatest depth found was 498 feet, between the eastern part of Battle and Cherry Bluffs, and the middle of the lake was found to be continuously greater than 400 feet in depth from this place to about opposite Six-mile Point, a length of nine miles. The part of the basin below 400 feet, is both deepest and widest toward the upper end of the lake. The lake is almost certainly in part a rock basin, for although the fan from Deadman River is partly accountable for the height of its water-surface, the character of the valley below, is such as to show that it could at no time have afforded free drainage to the deeper basin of the lake at the present relative levels.

Peculiar conditions of this lake.

The lake has therefore the general character of a fiord or fiord-lake, but differs completely from these in not being related in the usual way to a mountain range. It lies, it is true, in a hilly country, but one which is still essentially a part of the Interior Plateau, where the main



direction of glaciation is nearly transverse to it ; and although the ice of the glacial period may have had something to do with clearing the débris from its hollow (see p. 258 B) it does not appear possible, under any circumstances, to consider it as the result of glacial erosion.

Mode of formation doubtful.

The question of the mode of origin of this lake is one deserving further inquiry, and requiring comparison with fiord-lakes such as the Shuswap Lakes. I will here only add, that it seems most easily applicable on the hypothesis of local changes in elevation of the surface by which this part of the Thompson Valley, after its excavation, became relatively depressed. Such a movement may have been accompanied by faulting, evidences of which at a date posterior to the Miocene are found near both ends of the lake. It will be noted, however, that this supposition does not accord with the permanence of relative level of the surface assumed in connection with the origin of the early Pliocene valleys. The matter is still an open question.

Nicola Lake.

A part of Nicola Lake is also included by the map. A few soundings made in this lake, near the south line of the map, showed the bottom to be almost perfectly flat, with a depth of 130 to 150 feet. In Bonaparte Lake, no soundings were made, but the shelving character of its shores indicate that it is probably not very deep. In connection with the theory of a relative depression of a portion of the surface of the Interior Plateau, it is worth noting that the three large lakes of this district lie nearly in line, north-and-south, though each of them is transverse to this general direction.

Bonaparte Lake.

MINERALS OF ECONOMIC VALUE.

Object of this chapter.

In the following pages, the conclusions respecting the distribution and mode of occurrence of placer gold which result from the geological study of the region here reported upon, are given in summarized form. This is followed by notes on the various deposits of ores and other useful minerals, including details not given in the foregoing sections of the report, and referring, wherever necessary, to these pages.

AURIFEROUS PLACER DEPOSITS OF DIFFERENT PERIODS.

Investigation for sources of gold.

One of the more important questions of an economic kind connected with the particular region here described, but one which is common also to the greater part of British Columbia, is that of the sources of the gold contained in the placer deposits of the rivers and streams. In investigating this, it is desirable not only that quartz-veins traversing the older rocks should be examined, but also, from the generally close

associations of gold with pyrites, that any considerable masses of rock which have become charged with pyrites should be tested, and that attention should further be given to the conglomerates found to occur in the several formations, representing as these do, the river wash or shore work of former periods of denudation and concentration. With this object in view, specimens were collected from a number of localities, during the progress of the geological work, and of these, those which appeared to be the more important, by reason of their mass or because of other circumstances, have been subjected to assay in the laboratory of the Survey. Assays made.

In most cases, specimens of this kind naturally prove to contain nothing, but where they are found to hold traces of gold, this may be taken as an incentive to further examination of the deposits. The following is a list of specimens examined of pyritized rocks, very often in a decomposed and rusty state, which yielded traces of gold:— Pyritous rocks containing gold.

1. Decomposed syenitic rock with pyrites. Near the little lake shown on the map to the south of Edwards Creek.

2. Decomposed rocks (quartzites?) of the C  che Creek formation. Red Hill, $4\frac{1}{2}$ miles south of Cornwall Creek and $\frac{1}{4}$ mile east of the wagon-road.

3. Rusty quartzite, $1\frac{1}{2}$ miles west of northern part of Stump Lake. Ferruginous deposit with basalt. Clinton Creek, above the

4. Reddish quartzite, $7\frac{1}{2}$ miles north of Clinton, at east base of Marble Mountains.

6. Rusty, shattered and altered rock. Near north edge of Granite. Great Rock-slide, Thompson River. Gold trace. Silver 0.175 oz. to the ton.

7. A considerably metamorphosed greenish-gray rock, 'apparently' clastic, with grains of iron- and copper-pyrites. In-kai-kuh' Creek, Thompson River. A mile east of the railway.

8. Shattered and dolomitized rock. Near the wagon-road between Kamloops Ferry and Tranquille.

9. Decomposed and rusty diabase rock. East side of Nicola Lake, half a mile from the head of the lake.

10. Shattered, rusty Cretaceous rocks, near mouth of Texas Creek, Fraser River.

The following specimens afforded no trace of gold:—

11. Decomposed schists, $4\frac{1}{2}$ miles south of Cornwall Creek and $1\frac{1}{4}$ mile west of the wagon-road. Trace of silver. Pyritous rocks without gold.

12. Rusty decomposed volcanic rock. Cairn Mountain, Clear Mountain Range.

13. Rusty decomposed rock. Hills south of Nicola Lake, $1\frac{1}{2}$ mile east of outlet.

14. Decayed and rusty schists. East side Napier Lake.

15. Rusty, ochraceous rocks, forming wide zones in the formation. West side of Fraser River, three miles above Fountain Creek.

16. Shattered and pyritized rock of the C che Creek formation. Wagon-road $2\frac{1}{2}$ miles north of Hat Creek.

17. Quartz and wad. Clinton Creek, above the town.

18. Red and purple quartz or quartzite. In drift at Clinton.

19. Silicified and rusty quartzite. Cretaceous. One mile east of Fountain Creek, near the wagon-road.

20. Rusty, shattered, and altered rock showing some copper carbonates. Near north edge of granite, Great Rock-slide, Thompson River.

Referring to the foregoing assays, the following notes may be added respecting a few of the localities represented which appear to me to warrant further investigation as possible sources of gold in paying quantities.

Syenite with gold.

No. 1. The syenitic rock met with near Edwards Creek, is peculiar in its character and appearance and is evidently a true intrusive mass (see p. 246 B). It contains a considerable proportion of pyrites, which is evidently auriferous, and it is quite possible that some portion of this mass may prove to contain a workable quantity of gold, constituting a deposit of low grade, but obtainable in large quantity at an almost nominal cost. Gold was not only found in this rock on assay, but also observed in a thin slice, microscopically examined. The syenite intrusion extends for a considerable distance in a south-eastward direction, beyond the limits of the Kamloops sheet.*

Crushed pyritous rocks.

No. 2. The shattered and reddened rocks of some parts of the C che Creek formation, in the vicinity of the Thompson and Bonaparte rivers, constitute a striking feature (see p. 80 B). The reddened rocks are largely either quartzites or rocks of other composition more or less completely silicified. At the surface they appear as red or yellow crumbling slopes and low hills, but in depth it is found that they are charged with large quantities of disseminated iron pyrites. The quantity of rocks of this character is practically unlimited, and the assay quoted

* Attention has very recently been drawn to the auriferous granites of the Timbarra gold-field, New South Wales, rendering the above-mentioned occurrence all the more interesting. Records Geol. Surv. N. S. W. vol. IV., part IV., p. 164.

shows that they contain some gold, at least in certain parts of their extent. It therefore appears to be well worth while to thoroughly sample the exposures of rocks of this class, wherever they present themselves, for in event of the recognition of any zone in which a payable quantity of gold may occur, an enormous quantity of lower-grade milling ore might be obtained from them and worked with ease. No. 6 may be classed under the same head, as representing an extension of the altered Cache Creek rocks above alluded to.

The discovery of several loose specimens of rock containing richly auriferous hæmatite, in the gravel deposits near Clinton, has been noticed in a previous report.* Inquiries made on the spot, show that such specimens, consisting of jaspery hæmatite with quartz, have been found in three separate places near the west end of the town of Clinton, and one of these, subjected to assay, is reported as yielding gold to the value of \$300 to the ton. The source from which these fragments have been derived has not yet been ascertained, but the gravelly mounds in or near which they occur, are evidently of the character of moraines, due either to the period of recession of the main Cordilleran glacier, or to that of local glaciers of somewhat later date. In the first cases, the origin of the loose material should be sought for to the north-north-westward, somewhere along the eastern watershed of the Marble Mountains; in the second, probably more to the north-westward, but in either case in some part of the Marble Mountain range or in its vicinity. In the same gravelly deposits, specimens of red quartzites or silicified argillites occur. These are not very abundant, but their occurrence is rather unusual in this region. Thus, when in travelling northward from Clinton specimens of similar red rocks were found from time to time, till rocks of the same character were found in place at the east base of the Marble Mountains between Clinton Creek and Sandy Creek, it appeared to be probable that the source of the associates of the auriferous specimens, at least, had been discovered. No. 5 of the foregoing list, represents the rock found at this place and it proved to contain, as will be observed, traces of gold. It would thus appear, that the eastern edge and the eastward slopes of the Marble Mountains, well deserve to be closely examined and searched for the possible place of origin of the richly gold-bearing specimens first alluded to, the clue being in the first instance afforded by the general study of the character and direction of the glaciation by which the country has been affected.

Rich 'float' near Clinton.

Its probable origin.

Passing now to the second class of possibly auriferous materials above alluded to, the conglomerates of various ages, it may be

Conglomerates carrying gold.

* Annual Report, Geol. Surv. Can., vol. III. (N.S.) pp. 54 B, 144 B.

Specimens
examined.

explained, in the first place, that to test these thoroughly, a considerable mass of rock in each case, should be pulverised and sampled in order to obtain a specimen entirely suited for assay. This arises from the fact that such conglomerates may be expected to contain visible grains or pellets of gold, like those met with in the more recent placers, that these may be but sparingly distributed and that large masses of intervening rock may be practically barren. The means were not at hand to subject the conglomerates met with to treatment of this kind, and the specimens actually assayed have been merely hand specimens, so that the investigation of the possibly auriferous character of the conglomerates must be regarded as being as yet very incomplete. The assays actually made have, moreover, been confined to a small number of conglomerates, all of Tertiary age but two, which are Cretaceous. The following is a list of such assays :

1. Rusty Cretaceous conglomerate. Cliff to the east of the Fraser opposite Lillooet Bridge (p. 152 B). No gold.
2. Rusty Cretaceous conglomerate. East side of mouth of Botanie Creek (p. 153 B). No gold.
3. Cherty conglomerate (Oligocene). Near Copper Creek (p. 162 B). Traces of gold.
4. Cherty conglomerates (Oligocene) one mile south of Lac à la Fourche (p. 69 B). Traces of gold. (This locality is situated some miles beyond the edge of the present map—about 12 miles south of Nicola Lake, in the valley of McDonald River or Quilchenna Creek.)
5. Rough basal conglomerate (Oligocene). Plateau 2 miles south of Thompson, opposite mouth of Deadman. Traces of gold (p. 160 B).
6. Outlier of dolomitic conglomerate (Oligocene). Gardé Lafferty, north of Kamloops (p. 163 B). No gold.
7. Cherty conglomerate (Oligocene). Hat Creek (p. 212 B). No gold.
8. Cherty conglomerate (Oligocene). Near McLean Lake (p. 213 B). No gold.

Gold in Oligocene conglomerates.

It thus appears, that in three localities of the occurrence of the peculiar cherty conglomerates of the lower Tertiary, traces of gold have been found. In three other Tertiary conglomerate specimens, and in the two only specimens of Cretaceous conglomerates examined, no gold has been found. It may, I think, be assumed that wherever traces of gold can be detected in a hand specimen of a conglomerate, it is worth while to further examine the deposit, to investigate particularly its lower layer upon the old bed-rock if this can be reached, to test in succession each of the superposed beds which shows points of difference, and to seek for any layers in which notable

* A
† C

quantities of pyrites, magnetite or other heavy minerals have accumulated. Magnetite is perhaps the most constant associate of gold in placer deposits of all kinds, and a ready mode of ascertaining its presence in conglomerates is found in pulverising these and applying the magnet to the powder.

It is not necessary to enter at greater length into this general subject. Some remarks upon it will be found in my previously published *Mineral Wealth of British Columbia*.^{*} It need here only be added that the coincidence of the belt of Cretaceous rocks, holding much conglomerate, with the line of the Fraser River, which in its recent placers has proved to be richly auriferous, suggests the possibility that the gold found may in part have been derived secondarily from these conglomerates. The proximity of the conglomerates to the schistose and slaty rocks of the same region, from veins in which most of the gold has probably been originally derived, in itself affords some reason to assume the existence of gold in these conglomerates. On the other hand, the great abundance of diabase and diabase-like fragments in the conglomerates, may show that the distinctively gold-bearing rocks were not at the time supplying much material towards the formation of the conglomerates. The composition of the early Tertiary (Oligocene) conglomerates is in general very different. Their material has been very largely derived from the outcrops of the lower parts of the Câche Creek rocks, to the east of the main limestone belt. These rocks are traversed by very numerous, though generally small, quartz-veins and the occurrence of more or less gold in their debris, wherever this has been properly concentrated by natural agencies, may be looked for with considerable confidence. It appears to be probable, for example, that gold found in Criss Creek has been derived from these conglomerates, which are cut through by it.

Composition
of various con-
glomerates.

None of the older conglomerates of the Câche Creek formation, found in limited beds on and near the North Thompson, have been examined for gold.

Since the above notes on the possible occurrence of workable auriferous conglomerates in British Columbia were written, additional encouragement to investigation in this direction has been given by development elsewhere. The continued and vast importance of beds of this character in the Transvaal may be alluded to. In California, Mr. R. L. Dunn has lately described Cretaceous conglomerates which have proved to contain payable gold and have been the source of local placers;† and in Central Otago, New Zealand, Mr. A. McKay tabu-

Experience
elsewhere.

^{*} Annual Report, Geol. Surv. Can. vol. III. (N.S.) p. 47B, *et seq.*

† California State Mining Bureau, 12th Report (1894), p. 459.

lates seven or eight "auriferous wash-drifts" of which four are of Cretaceous or Tertiary age.*

Different systems of Tertiary rivers.

The older Tertiary or Oligocene conglomerates above referred to, represent remaining portions of the products of the earliest great period of Tertiary denudation. It is elsewhere explained (p. 69 B) that these beds subsequently suffered some disturbance, at least locally, and that during a succeeding period of considerable duration, denudation again progressed actively. A new or considerably modified system of drainage must at this time have been produced. This period of waste was brought to a close by the great volcanic eruptions of the Miocene, and these must undoubtedly have covered up many stream- and river-beds of the time. The quantity of volcanic products due to this period in the area of the present map, must have been such as to entirely obliterate the previously existing drainage system, the evidence being that all, or nearly all, the valleys of the present rivers and streams, have since been excavated along new lines, largely determined in the first instance by the distribution and local mass of the volcanic accumulations which gave form to the surface.†

Pre-Miocene erosion.

Whenever these later erosions, whether confined to the valleys of streams or extending more widely from these, have cut down to the old pre-Miocene surface, any gold which may have been contained in the old stream-courses of this surface has of course been redistributed and has gone toward the enrichment of the modern gravels. But where the volcanic rocks remain, the old drainage-channels probably still exist beneath them intact. In districts based upon the older rocks referred to the C  che Creek formation, these channels may reasonably be expected to contain more or less gold. This is, however, less probable, where the underlying rocks are those of the Nicola formation.

Drainage system buried.

Very few instances are found in the Kamloops sheet, in which basaltic or other volcanic rocks still actually floor valleys antedating the Miocene volcanic period. The valley between the Marble Mountains and Edge Hills is, however, probably a case of this kind, and it is possible that parts of an old channel may exist here beneath the basalts. In most cases, there is no existing indication of the position of such old drainage-channels, and as a matter of fact none such had yet been exploited. It is quite clear, however, that large

* Geol. Reports on Older Auriferous Drifts of Central Otago (1894), pp. 33, 34.

† On the general subject of the physical features at different periods and the epochs of denudation and deposition, reference may be made to a paper by the writer on the Later Physiographical Geology of the Rocky Mountain Region in Canada. Trans. Royal Soc. Can., vol. VIII., sect. IV., 1890.

relatively-level tracts now covered by basaltic or other volcanic rocks, such as those of the Green Timber, Bonaparte, and Arrowstone Hills plateaux, must have been provided with well developed systems of drainage before the time at which they became covered with volcanic products, and it can scarcely be doubted that some at least of these will yet be discovered, and followed up if they should be found to yield gold in payable quantity.

Some of the occurrences of gold in the gravels of existing rivers and streams, very possibly depend on the robbing by these rivers of pre-Miocene placers. Thus, the local occurrence of coarse gold on the Thompson, near Nicoamen, is difficult of explanation except on this hypothesis. The Tertiary rocks, including sedimentary materials below, and consisting entirely of volcanic rocks above, here overlap the steeply-sloping edge of the granitic rocks of the Scarped Mountains. It is almost certain that this margin of the old rock-surface continues to slope down beneath the Tertiary strata below the present river-level, and that if followed, it would terminate in the bottom of a pre-Miocene valley, now covered; though whether this may have drained to the northward or to the southward along the base of the granitic hills cannot be determined. The border of the Tertiary rocks in contact with the granitic materials, is considerably broken up and distributed, so that it may easily have happened that portions of the old valley-deposits have been brought up and have yielded their contained gold to the denudation of the present river. The explanation suggested in this case is of course merely a conjectural one, but it is instanced as an example of the manner in which a study of the geological conditions and history may assist in determining the most probable places in which to seek for the older auriferous deposits. (See p. 107 B.)

Possible robbing of early placers.

Nicoamen.

It is to be noted, that in the case of any auriferous gravels beneath the volcanic rocks of the Tertiary, these will have been exempt from the scouring and transporting action of ice during the glacial period, which has undoubtedly resulted, in the case of the more modern deposits, in obscuring and complicating the question of the origin of the gold, as well as in breaking the continuity of the deposits, and in some instances, probably, in dispersing concentrations of gold naturally brought about before that period.

Old gravels free from glacial interruption.

Another and still later system of old valleys occurs in the district, to which a few words of description may be given, for though no attempt is made, in the present Report to repeat in detail the study of the

Early Pliocene valleys.

successive physiographical events of the Tertiary, on which the paper last referred to may be consulted, it is desirable from an economic point of view to point out the various directions in which search for the older gold placers may be made. This system of valleys is referred to the Pliocene, or latest Tertiary period, the close of which is marked by the onset of the conditions of the glacial period.*

When the great period of accumulation of Miocene volcanic materials upon the surface of the Interior Plateau came to an end, there is reason to believe that the country stood at a level considerably lower than the present, relatively to the sea. The streams of the new drainage system which outlined itself, appear to have possessed rather low gradients, but their action was long continued, and resulted in considerable denudation. The streams themselves, in many cases appear to have excavated nearly to the maximum depth which the height of the country admitted, and to have produced somewhat wide, but usually not very deep, trough-like valleys, which may still be recognized in many places and which are generally still occupied by existing streams, though in some cases now interrupted or abandoned in consequence of later changes.

Later Pliocene erosion.

After this action had been in progress for a long interval, a very considerable and general elevation of this part of the Cordilleran region must have occurred, by which the gradients and powers of erosion of the rivers became greatly increased. A comparison of the average levels of the old valleys with that of the present levels of the Fraser and Thompson in their vicinity, leads to the belief that this elevation must have amounted to about 3200 feet.

Great changes effected at this time.

The results of this great increase in the elevation of the land were important. Such rivers as the Fraser and Thompson, fed by the perennial snows of extensive mountainous districts about their sources, were then enabled, by the increased gradients given to them, to cut down so rapidly as compared to other streams less copiously supplied, that they become the main drainage-channels of the country. From the low levels thus soon achieved by these main streams, their lateral branches cut back rapidly in some cases trenching the bottoms of the valleys of the earlier Pliocene erosions with deep newly cut ravines, in others crossing them and diverting their waters to new and more direct courses. Thus great changes were worked on the drainage system of the region as a whole, and the system of water-

**Ibid.* p. 16, et seq.

courses as it now exists, was, in respect to all its main features, completed.*

In the following list, the best marked examples of the early Pliocene valleys of low gradient met with in the Kamloops sheet, are enumerated. The elevations set opposite the names of the several streams, are those ascertained for the lower remaining parts of the old valleys, below which, in each case, the existing stream falls into a steep gorge-like valley, which it descends to one or other of the main river-valleys, or to some deeply cut tributary of these :

	Feet.
Meadow Creek (upper valley).....	3,350
Pukaist-Creek (").....	3,750
Witches Brook (").....	3,650
Three-lake Valley (south part).....	2,750
Kelley Creek (lower part) and Junction Valley.....	3,300
Câche Creek (upper valley).....	2,650
La-loo-wassin Creek(upper valley)	3,450
Pavilion Creek.....	2,300

A careful inspection of the map, with its contour-lines and the elevations otherwise noted upon it, will afford more information on this subject than any further general description could give. From what has already been stated, it will be evident that wherever the early Pliocene valleys have been excavated on or near to areas of the older rocks, and particularly those of the Câche Creek formation, placer deposits of gold referable to the time of erosion of these valleys may be looked for. It must be borne in mind, however, that these valleys lay open to the work of the ice of the glacial period, and that it is probably in the main, if not alone, in such of them as lie transverse to the general direction of motion of this ice, that placer deposits may be expected still to remain intact. Where the direction of the old and wide valley nearly coincided with that of the motion of the Cordilleran glacier, it is probable that in most cases the original deposits may have been swept out to the bottom by this agent.

* It may be appropriate to note here, that much remains to be ascertained in detail, respecting the progress and various arrests of the post-Miocene period of erosion. Many interesting details are yet to be explained. A subsidiary feature of this kind, and one of some importance, occurs in the vicinity of Kamloops lake, where the rocky bottoms of wide trough-like valleys, into which the modern streams of the lower parts of the Tranquille and of Copper Creek have cut, have an elevation of about 800 feet above the present lake (1900 to 2000 feet above sea-level.) The terrace-like main bottom-level of the Thompson valley near Eight-mile Creek, is nearly the same, and the evidence appears to show an epoch of stability of some duration, between that of the low elevation of the early Pliocene and that of the high elevation of the later Pliocene. The notably low and wide valley of the lower Deadman, unless it may be assumed to be due to faulting at the time mentioned in pages 175 B, 310 B, likewise awaits explanation, being otherwise apparently inconsistent with the course traced out for the formation of the Old Câche Creek valley (p. 320 B.)

Instances.

Old Cache
Creek.Pass Lake
Valley.Three-lake
Valley.Events of gla-
cial period af-
fecting gold
deposits.

By reason of the character of the rocks through which they are in part excavated, and because of their direction relatively to that of the general glaciation, the Kelley Creek and Junction Valley, together with the higher or early Pliocene valleys of Pavilion Creek and Cache Creek, appear to be, amongst those above enumerated, the most likely to contain old gold places beneath their more recent filling of drift deposits. The upper valley of Cache Creek has been particularly instanced in the paper already referred to, (p. 19 *et seq.*) and is there shown on a special map. It may be traced upon the Kamloops sheet, following the Pass Valley eastward, crossing the Deadman River, continuing by the Red Lakes to the Tranquille River, nearly following this river for some miles, then crossing the Middle Fork and Watling Creek above their mouths and reaching the Garde Lafferty by Lake. In this instance, the water which originally flowed through the old valley appears to have been intercepted at several points by Eight-mile Creek, Deadman River and the Tranquille River, all discharging at right angles toward the great later valley of the Thompson. The only portion of this particular early Pliocene valley which was excavated in possibly gold-bearing rocks, is its eastern part, toward the Garde Lafferty. This part may not only have obtained some gold directly from veins in the schistose argillites of that vicinity, but is also known to have been engaged in carrying the denuded material of the older Tertiary conglomerates, of which remnants are still found there. It would thus appear, that the valley in which Pass Lake lies, may still contain some of the old auriferous gravels of the early Pliocene, in the lower deposits filling it, and that it is very possibly to the subsequent robbing of such old placers, that the auriferous character of the lower part of the present Tranquille Valley is due.

The Three-lake Valley, enumerated in the list just given, appears to be a special case. There is some reason to suppose that the Fraser River, before it cut through the Cretaceous ridge near Fountain, flowed for a time through this valley. That the valley is deeply filled with drift deposits, is shown by the disappearance of streams which flow into it and the subsequent reappearance of their waters in springs in its southern part. The trend of this valley is, however, such that the ice of the Cordilleran glacier must have flowed almost directly along it, and this circumstance renders it doubtful to what extent any auriferous gravels which may be supposed to have been deposited in it, still remain there undisturbed, beneath the modern cover.

In outlining the history of the recent denudation of the country, we have now arrived at a time in which the deep valleys of the Fraser and its main tributary the Thompson were formed. The next event was the

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spread of the ice of the Cordilleran glacier over the whole region. The conditions thus brought about and the changes produced, it has been endeavoured, as far as possible, to follow in foregoing pages. The resulting effects on the occurrence and distribution of gold in the Fraser and Thompson valleys, may now be alluded to, in the endeavour to follow the story of their gold accumulations, in the light of the geological investigation of the region. The succeeding notes on this subject, must be read in connection with what has already been stated respecting the glacial and post-glacial history of these great valleys.

Conditions affecting the Occurrence and Distribution of Gold Placers in the Valleys of the Fraser and Thompson.

The concentration of gold in certain layers of limited thickness, such as to form rich auriferous placer deposits, has without doubt occurred only during the periods of erosion or cutting out of the valleys. During the long period of erosion in which the great trough-like valleys of the Fraser and Thompson were originally produced, in the later part of the Tertiary era, analogy with other well-known cases leads us to believe that rich gold-bearing deposits must have been formed along the rivers. Where the river itself cut its way through auriferous rocks, as was doubtless the case along many parts of the Fraser and some parts at least of the Thompson, or where rapid tributaries which were engaged in excavating such rocks entered the main stream, deposits of 'coarse' gold must have been produced. The rapid current which undoubtedly characterized these rivers at this time, would naturally lead to the trailing of the finer particles of gold along their entire lengths. Had the miner been on hand to exploit the prehistoric placers, as they existed at the close of this long period of denudation, he would in all probability have found them to be richer and more regular in character than any of those discovered by the pioneers of 1858 and 1859. In Cariboo, it is believed that the richest old channels, such as those of Williams and Lightning creeks, met with beneath the boulder-clay, actually date from this period. A thick rib of the Cordilleran glacier must, however, have followed the north-and-south valley of the Fraser, and it is possible that, as a result, the pre-glacial river-gravels were either entirely removed or much displaced and disturbed. It is not known that any pre-glacial placers have been found or worked on either the Fraser or Thompson. What has already been said as to the reaches of the Fraser in which its post-glacial channel is still higher than the level of the old pre-glacial rock-floor (p. 307B), shows

Original conditions in Fraser and Thompson valleys.

Pre-glacial channels not yet tested.

it is to be possible, that if spared by the great glacier, portions of this old channel may yet remain, though below the water-level, and therefore very difficult of access.

Gold disseminated in boulder-clay.

Much of the material which must have filled the old channel, together with debris from a distance, may doubtless have been incorporated in the boulder-clay, but the mass of this deposit is so thoroughly commingled, that whatever gold may occur in it must now be sparingly and irregularly disseminated. It is likely that the next important concentration of gold, occurred during the later time at which the boulder-clay itself became subject to denudation, and some placer deposits may yet be discovered in the gravels due to this period of waste, such as those found overlying remnants of boulder-clay near Ashcroft (p. 273 B).

Later glacial concentration and filling of valleys.

In the succeeding period, during which the large valleys were again being filled with detritus while they were in a flooded state, a certain amount of gold was no doubt also brought into them, whether from the transport of material from the boulder-clays of the adjacent slopes, or that derived directly from the waste of rocks then in progress. Such gold must, however, have been irregularly distributed through the entire mass of the deposits which went toward filling the large valleys, and only in certain places, where streams brought their material from richly auriferous localities, can it be supposed that these deposits as a whole—whether horizontally arranged or in the form of fans—may contain enough gold to enable them to be worked at a profit.

Post-glacial concentration.

When, however, the post-glacial erosion of the Fraser and Thompson valleys began, the conditions were changed. The rivers in gradually cutting down through the drift-filling, swung from side to side of the often wide valleys, so that the surface of every river-terrace may be considered as more or less exactly representing part of the bed of the river at a certain stage in its descent.

Gold deposited in various old channels

In each of these old river-beds, a certain proportion of the gold, which had been disseminated in the material cut away and removed by water, became concentrated; and when the river cut down to a still lower stage, this was left in the gravelly and bouldery wash of the old bed. In most cases, however, these beds were in turn cut away by the river when operating at a still lower stage, and thus instead of continuous river-channels at various elevations, we find only the bouldery and gravelly materials of parts of old river-beds, capping more or less irregular and limited terrace-flats. It will further be obvious, that whenever a lower and newer channel of the river, in the course of this

period of denudation, either coincided with or cut across any portion of an older bed, this would be robbed of its accumulated gold and the later river-bed would be correspondingly enriched locally. This, with the original differences in richness which must have existed as between different places, goes far to explain the varying character of the placers met with on the several terraces, or benches along the valley and in the bars of the modern river. It will also be apparent that, other things being equal, the lowest and latest river-channel should be the richest, for though in the progress of those changes a considerable part of the gold must have become so highly comminuted as to be carried away by the stream and altogether lost, and though other portions of it were left on the rearranged surfaces of the river-terraces, a considerable proportion of the whole amount originally contained in the drift-filling of the valley, must in the end have been concentrated in the bed of the present river.

Latest channels richest.

The foregoing considerations may appear to be of a somewhat theoretical character, but most of them scarcely admit of doubt, and the conclusions arrived at agree with the facts as observed by the miners. It is thus of importance to clearly picture to the mind the way in which the placer deposits were formed, in order to recognize the places and conditions under which they should be sought for. Miners who have worked upon the 'benches' of the Fraser and the Thompson, affirm that the payable gold (which except in certain limited localities is usually fine) is invariably, or almost invariably, found in a yellow layer a few inches to a foot or more in thickness, not far below the surface of each bench, and very generally in association with a coarse bouldery or gravelly wash. The appearance of nearly all the old claims, most of the richest of which were worked out many years ago, tallies with these statements and with the explanation of them above given. It is not merely that the mining ceased to be profitable when a certain depth of cover was exceeded, for in many cases a good head of water was available, and if recurrent pay-streaks had existed throughout the thickness of the benches, these could in such instances easily have been sluiced away and the whole of the gold obtained. The general mass of the material composing the terraces or benches along these rivers has not been proved to be payable when worked by ordinary rough methods. When such work is entered into, the miner is called upon to concentrate disseminated deposits, like those which have elsewhere been concentrated naturally for him by the river itself.

Actual mode of occurrence of gold.

Confined to certain layers.

Deposits suited for hydraulic work.

The question is often asked—In a valley which has proved to be so richly auriferous as that of the Fraser, may not the terraces everywhere be profitably worked by the hydraulic method on the large scale? So far as a limited experience of the method goes, this does not seem to be the case, but it may be considered as demonstrated that some portions at least of the great mass of terraced deposits which still remain in the valley, are susceptible of profitable treatment by this method. One or two trials will not test this important matter completely, and in further endeavour towards its solution, it is necessary to bear in mind the general principles governing the formation of the placer deposits as a whole. The most favourable places for such further trials, are doubtless those in which rapid tributaries from known auriferous districts have piled their débris into the old valley of the Fraser. Of these Cayoosh Creek is probably the best known at the present time, and it may be considered as quite within the bounds of probability, that the terrace materials in the vicinity of the mouth of this stream, at least, will prove to justify operations on a large scale.

Van Winkle Hydraulic Mine.

Since the foregoing pages were written, hydraulic work carried out at Van Winkle Flat, about two miles above Lytton, has supplied new information on the character of the gravels of the Fraser Valley, which goes far to bear out the views previously expressed. A good hydraulic plant has been established at this place, with the object of working the whole mass of the higher terraces or benches, which rise from the river in successive steps towards the base of the mountains on the west. In 1894, an excellent section was found in the hydraulic pit, running back from the river for about 1200 feet. The character of the work is described in the summary report for 1894 (p. 17 A). The river-flat, originally worked by hand, as well as some parts of the edges of an older river-channel now about 100 feet above the stream, proved to be rich in gold; but the yield from the hydraulic workings had not, at the time of my visit, fully realized the anticipations of the owners.

It is here proposed, with the aid of the annexed diagram, and as a type of the structure of the drift materials found in this part of the Fraser Valley, to briefly explain the character of the deposits exposed.

Section seen in it.

The river-flat (*d*), a few feet only above high-water, is not actually cut across by the line of sluices, where the first principal terrace (*c*) rises steeply from the river to a height of about 100 feet. The next terrace (*b*) is about sixty feet higher, and there are other irregular terraces at still greater heights.

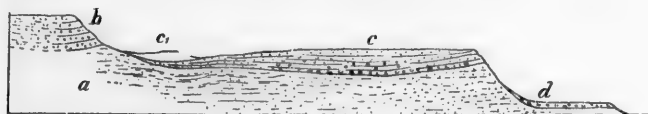


FIG. 16.—SECTION AT VAN WINKLE HYDRAULIC MINE, FRASER RIVER.*

- a. Deposit formed in valley during time of flooding (White Silt period).
- b. Material filling an early river-channel of the succeeding period of erosion.
- c. Material filling a later river-channel of the same period, with (c¹) marginal flood-deposits of the same date.
- d. River-flat covered by still later river deposits and near the level of the existing river.

No true bed-rock is seen, the bottom of the old valley being here evidently below the present river-level, nor is any boulder-clay exposed, this, as elsewhere explained, having been removed during a period of erosion antedating that of any of the deposits met with. The lowest and oldest of these deposits (a) consists, near the river (where it forms the greater part of the bank) of well-rolled gravels and small or medium-sized boulders, yellowish-gray in colour, irregularly and somewhat obscurely stratified and with sandy rather than clayey material filling interstices. Further back from the river, this deposit is found to change into coarse and irregularly stratified sands and fine gravels of darker colour, sometimes more or less cemented. Cemented layers of this character constitute the only approach to bed-rock so far found. This deposit evidently represents the material with which the valley was filled during a lacustrine epoch, or one in which the valley was from some cause flooded. Its surface has probably been, at least in some places, as high as the highest remaining terraces, from which it has been cut away at a later time by the river, as the stream gradually worked down to the present level.

Deposits of period of filling.

Remains of old river-wash may therefore be looked for on even the highest terraces, but the highest old channel here actually cut into, is that marked b. This shows yellowish stratified gravels with some bouldery layers, but had not been exposed to its bottom at the time of my visit.

Deposits of period of excavation.

The lower river-channel must in each case be the newer, and on the arrangement assumed in the diagram (in all probability correct) the next deposit in order of time is that marked c, representing the filling of another river-channel, fully exposed in the work. This consists chiefly of gray gravels with very coarse bouldery layers in the bottom,

Series of old channels.

*Compare with section on Thompson River, p. 306 B.

but on the inland side, is gradually replaced by stratified sands, containing some silty and some gravelly layers, which evidently represent the flood-overflow deposits of the same period. They are indicated by the letter *c*¹, and the monitor stood upon them at the time the sketch was made. The gravels of the river-flat (*d*) represent a portion of the deposit made by the river at a still later date, when it had nearly reached its present level.

Contents in gold.

In gold, the older deposits (*a*) are poor, as might be anticipated from their comparatively unsorted character and the fact that no auriferous tributaries are known to enter the valley in this part of its length. The gold so far obtained, has been chiefly from the gravels marked *c*, but the quantity has been only moderately remunerative. The gravels *b*, where prospected, show evidence of more gold, but the most highly concentrated deposits of this section have evidently been those of the river-flat and of the banks and bars of the present river.

Origin of materials.

That the older material filling the valley (*a*) is largely of local origin, seems to be shown by the fact that, at a short distance below the works, a bouldery point and bar, extending across the river and crowding it against the Cretaceous rocks of the east bank, occurs in manifest relation to a small valley here entering that of the Fraser from the mountains on the west. The filling of the old channels is probably largely composed of the rearranged material of *a*, but doubtless also with the addition of much gravel trailed down by the current of the river, and the contained gold in each case must be supposed to have had the same double source.

Early placer mining.

The subject of the actual working of the gold placers of the Fraser and Thompson, has been treated in some detail in my Report on the Mineral Wealth of British Columbia.* It is now largely historical, and much information gained by the early miners in the course of their work, has lapsed beyond the possibility of recovery. Placer mining along these rivers was begun in 1857, 1858 and 1859, and the aggregate yield for these years alone, amounting to not less than \$1,700,000, was derived almost entirely from these rivers, though in part from portions of the Fraser to the north and south of the present map. This mining was conducted on river-bars and benches with the rocker and by sluicing, and work of the same kind, though with less important results, has never since been entirely interrupted. The placer mining of the future along these valleys is, however, likely to be conducted by improved hydraulic methods and by dredging appliances in the river bed.

General conditions found.

A list of the bars worked in the early years of mining on the Fraser, as complete as it was found possible to compile, is given in the publica.

* Annual Report, Geol. Surv. Can., vol. III. (N.S.), pp. 24 B-29 B, 115 B-119 B.

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tion just referred to.* Upon an examination of this admittedly incomplete list, the following observations bearing on the part of the river included in the present map, are based.—“From a point on the river a few miles below Boston Bar (about sixteen miles above Yale) to Sisco Flat, (a short way below Lytton) a distance in all of about twenty-five miles, rich deposits of ‘heavy’ gold were worked. Further up the river is a second run of ‘heavy’ gold, the limits of which can not now be so well defined, but which appears to have extended from a point about half-way between Lytton and Foster’s Bar, to some little distance above Fountain. Here nuggets of some size were occasionally unearthed, and there were some exceptionally rich diggings. On the Thompson, the vicinity of Nicoamen, where the original gold discovery occurred, has always been noted for its ‘coarse’ gold.”

Where upon these large streams the river-bars only have been mined, all signs of such mining disappear each year, in consequence of the descent of the flood-water of summer, but wherever the mining has extended to the terraces or benches, its traces remain. Thus, apart from our knowledge of the fact that almost every bar in the length of the Fraser included by the map has at one time or other been worked over, the evidences of bench mining are alone sufficient to show that this whole length has been more or less richly auriferous. Such traces are less conspicuous in the case of the Thompson River, and the evidence is that it was found to be much less continuously gold-bearing. Had we a complete plan of the Fraser, upon a sufficiently large scale, on which all the benches, with the areas occupied by solid rock and the patches upon which mining has been conducted were laid down, it would enable us to gain a pretty clear idea of the probable relations of the present stream to the pre-glacial one, both in regard to the elevation of the latter relatively to the former and to the manner in which the older concentrations have enriched some parts of the present river. No such general plan has yet been attempted, but a small part of the river which has been sketched with these points in view, is here presented as an example. It may be added, however, that to any one examining the river, with a just appreciation of the facts of its history as here outlined, the relations spoken of are quite apparent on the ground, and that these will doubtless be studied on the spot by the miner and all promising places prospected at the same time.

It may, however, be stated, that several places were seen along that part of the river above Fountain, in which the existence of an old drift-filled channel, with rocky sides, appeared to be very probable. One of these occurs on the east side of the river opposite Black Hill Creek ;

Auriferous
parts of val-
leys shown by
old work.

Illustration of
conditions on
Fraser.

Drift-filled
channels
noted.

* *Op. cit.* p. 115 R. *et seq.*

another, though in this case a very short length of old channel, may occur about half a mile below Kelley Creek, on the west side of the present river; a third, where the channel is probably three-quarters of a mile in length, is two miles below the point at which the Fraser enters the map-sheet, also on the west side of the river.

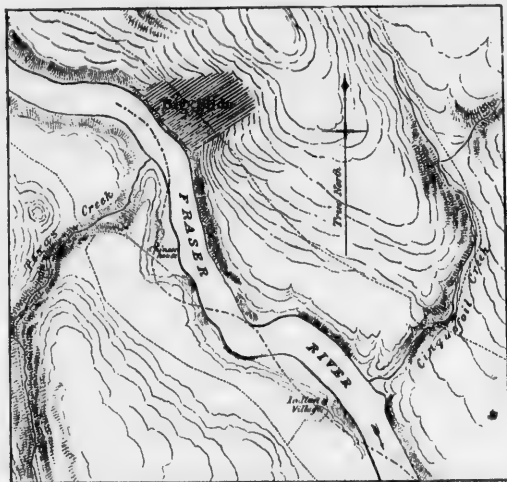


FIG. 17.— SKETCH-PLAN OF PART OF FRASER RIVER, NEAR TEXAS AND CINQUEFOIL CREEKS.

Illustrating the relations of the pre-glacial and modern channels of the river and the position of alluvial gold deposits. The probable course of the pre-glacial channel, shown by dot-and-dash line. Rocky bluffs, shown in heavy hachures; bluffs or banks of gravel, in lighter hachures. Parts of low 'benches' worked over for gold, stippled. Trails and routes shown by dotted lines. (Approximate scale, 108 chains=1 inch).

Recapitulation of placer deposits.

In recapitulation of the foregoing discussion, it would appear that the conglomerates and gravels of the district included in the subjoining list, are either known to be auriferous or may be regarded as probable or possible sources of gold. The list begins with the older deposits, but does not include the still older conglomerates of the Cache Creek and Cambrian, less regularly developed and of which no tests have been made:—

1. Cretaceous Conglomerates.—No gold yet found.

2. Oligocene Tertiary Conglomerates.—Traces of gold found.

3. Miocene Conglomerates or buried river gravels.—Not yet discovered in this district, though sandstones and water-bedded tuffaceous rocks are known in some places.

4. Early Pliocene Gravels:

a. In high-level valleys.—Buried under drift deposits wherever remaining; not prospected.

b. Along main river-valleys.—Excavated and redistributed in succeeding period.

5. Later Pliocene Gravels.—Possibly in part still remaining along Fraser, Thompson and other deep valleys, and if so, probably in some places above, in others below the present river-level. These would undoubtedly be richly auriferous, but no such deposits appear yet to have been discovered or worked by miners.

6. Boulder-clay.—In this the gold is probably everywhere too much disseminated for profitable working.

7. Interglacial gravels, silts, etc.—These have constituted most of the drift-filling of the Fraser and Thompson at one period, and still form the mass of the river-terraces—probably containing payable gold in places.

8. Gravels and bouldery deposits capping river-terraces.—These, with the gravels of the next class, have been those chiefly worked on the Fraser and Thompson. Nearly everywhere auriferous along these rivers, and often elsewhere.

9. Modern river gravels.—Nearly everywhere auriferous along the Fraser, frequently so on the Thompson, and often elsewhere.

Other Placer Deposits Worked.

The following brief notes refer to other rivers and streams in the district, upon which gold working has been carried on. They are derived in part from the general list given in my *Mineral Wealth of British Columbia*. Gold on other streams.

Cayoosh Creek.—This is again referred to in connection with auriferous quartz (p. 338 B). It was not discovered to contain valuable placers till 1886, but has since been continuously worked by Chinese. In the first year it yielded 725 ounces of gold. Up to 1890, inclusive, it is estimated that gold to the value of \$160,000 had been obtained.* Cayoosh Creek.

*Report of Minister of Mines of British Columbia, 1890, p. 376.

The part of this creek which has been worked, is about five miles in length, extending from the flat land where it meets the stream from Seton Lake, as far up as the Bonanza mine. Throughout this part of its length, the valley is bordered on both sides by high mountains, and is never wide. The greater part of the gold has been obtained below the "cañon," in a length of about two miles; but the richest claims of all occurred in a distance of about 1000 feet above the "cañon," where the old rock-bottom of the stream was reached. Elsewhere it has not been "bottomed," for though still rapid, the stream has been blocked by rock-slides from the mountains, in such a manner as to lead to the accumulation of great quantities of gravelly deposits in it. All the gold obtained is coarse. The Enterprise Company of Vancouver, has been engaged for some years in endeavouring to open the lower part of the creek, just above the flat, for hydraulic working, by providing a channel deep enough to drain the old rock-bottom. In 1892 a tunnel was completed for this purpose at a cost of \$25,000, and work was continued in 1893 and 1894, although with only moderate returns, much difficulty being experienced in dealing with large boulders.

Bridge River

Bridge River.—Discovered in 1858, and soon prospected nearly to its sources, some mining being done throughout. The coarsest gold is reported to be found along the first ten miles from the mouth, further on, for about fifteen miles, more or less scale gold was obtained. Still further up, the river becomes rather slack and little gold has been got, though some gold occurs in all the tributary streams. A good deal of mining has been done of late years in the vicinity of the South Fork, which is reached by a journey of three or four days from Lillooet, *via* Seton Lake and across the mountains. It is reported that one nugget weighing 32 ounces was found five miles up Bridge River, and that in 1866 twelve Chinese miners obtained gold to the value of \$66,000 by wing-damming.

The part of Bridge River included by the map, flows swiftly in a deep, mountain-bordered valley not of great width, in the bottom of which the stream itself has cut a nearly vertical-sided trench, averaging about fifty feet in depth, with rocky walls. The rocks belong to the Cretaceous formation. Patches of terrace-deposits occur at various elevations up to 300 or 400 feet above the water, those at lower levels being flat, while the higher ones slope toward the axis of the valley.

Bonaparte River.

Bonaparte River.—More or less placer mining has occurred along the lower part of this stream, below C  che Creek. On its tributaries, *Hat Creek* and *Scottie Creek*, gold has also been found, but in small

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quantities. The lower deposits of an old valley, which leaves the Bonaparte three miles above its mouth and is followed southward by the wagon-road, may be worthy of examination.

Tranquille River.—Gold was discovered here in 1858, and appears to have been worked with little interruption ever since, chiefly by Chinese. For many years, twenty to thirty Chinese have been continuously employed here, but latterly the number has decreased and the earnings are now supposed to be small. The gravels worked are those of the bed and banks of the streams, with narrow flats adjacent to it, but in 1893 the miners began to pay attention to the benches on the west side of the creek. Arrangements have also been made by a company to begin hydraulic work on the gravels along the east side of the valley. Gold is said to have been found for a distance of eight miles in all up the stream, but the working has been practically confined to a length of three or four miles of the lower, narrow and cañon-like part of the valley. The gold is sealy and a little platinum is associated with it. Even the narrow lower part of the valley still holds considerable masses of gravels interstratified with silts, with which it has at one time been filled. These belong to No. 7 of the classification given on page 329 B, and may be found to contain sufficient gold for hydraulic working.

The origin of the gold in this valley is somewhat obscure. The main stream apparently flows throughout upon Tertiary volcanic rocks which can scarcely be supposed to be auriferous. Its branch, Watching Creek, drains a considerable area of argillites, etc., holding some quartz-veins, but the gold has not been traced up to this branch. It is possible, however, that in some places the lower part of the river may reach older Tertiary gravels, like those of which remnants are found on the Garde Lafferty. It is also possible, that gold has been carried into the valley from the slaty rocks or conglomerates of the Garde Lafferty by means of the cross valley from Lac le Bois or that of Pass Lake, while the last-mentioned old valley may itself still contain gravelly deposits of later Pliocene age. (p. 320 B.)

Nicola River.—Scale gold may be found along all that part of the Lower Nicola included in the map, but no work of importance has ever been done and the quantity of gold is probably small.

Upper Nicola River.—Gold was found and worked to a limited extent on this stream in 1887, just above Douglas Lake. The gold was coarse and was found upon bed-rock, but only on sloping surfaces, as no attempt was made to reach the bottom of the old valley. Some gold has also been found along the river between Douglas and Nicola

lakes, but it was probably unremunerative, as very little work was done. It is noteworthy, however, that all this part of the country has been very little prospected, though the abundance of slaty rocks with quartz-veins and their proximity to the granites, would seem to render it promising.

North Thompson.

North Thompson.—No part of this river within the limits of the present map, appears to have been found to yield much gold. Some of the river-bars at one time paid to work, particularly along the lower part of the river.

The following tributaries of the North Thompson are known to have yielded more or less gold.

Tributaries of North Thompson.

Jamieson Creek.—Some mining was formerly done on the lower parts of this stream. The gold is probably locally derived from veins like those elsewhere described (p. 336 B.)

Louis Creek.—It is reported that gold to the value of \$8 to \$10 a day to the hand was obtained here in 1861. Chinese and other miners have occasionally worked here since, chiefly in and just below the cañon, near the mouth of the creek. Higher tributaries to the south-eastward considered promising.

Barrière River.—Mining is reported to have occurred on this stream on a limited scale in 1861, but no particulars can be obtained. Running across between the Barrière River and Louis Creek, about two miles to the east of the North Thompson, is a well marked high valley. This is continued also to the north of the Barrière for some miles, when it runs out obliquely on the edge of the North Thompson valley. It reaches Lewis Creek above the head of the little cañon referred to on that stream. This valley is partly filled with drift deposits, but its rocky bed is probably about 300 feet above adjacent parts of the main river. It appears at one time to have been occupied by a pre-glacial representative of Louis Creek and possibly by the North Thompson, at a still earlier period. I was informed, that coarse gold has been obtained in the small stream which now runs northward out of this valley to the Barrière. If auriferous gravels should be found to remain in the bottom of this old valley, these might be worked by drifting, with free drainage.

Deadman River.

Deadman River.—A Chinese company worked for a season about the mouth of Criss Creek, but as the operations were not continued, the ground may be assumed to have proved poor.

Ray Creek.

Ray Creek.—'Prospects' of fine gold are stated to have been obtained on the lower part of this stream, near its confluence with Gui-

chon Creek. There is a notable development of gravelly terraces here, with a good head of water, but it is doubtful whether the gravels are rich enough to pay for work.

Cherry Bluff Creek.—Gold has also been found here and some work was at one time attempted, but without important result. Cherry Bluff
Creek.

GOLD- AND SILVER-BEARING VEINS.

Notes respecting a number of massive deposits, found to contain more or less gold, have already been given (p. 311 B); what follows relates to auriferous and argentiferous veins.

Stump Lake and Vicinity—

The metalliferous deposits found in the neighbourhood of Stump Lake, upon some of which a good deal of work of a preliminary character has been accomplished, are generally spoken of as the "Nicola mines." The geological character of the district, with the nature of the country-rock, the general course of the veins and the area within which the actual discoveries are comprised, have already been noted (see p. 130 B). "Nicola"
Mines.

The metalliferous veins already known in this somewhat limited district are numerous, and while it is perhaps probable, from their very number, that no individual lode will be found to possess great continuity, the work done is sufficient to show that a considerable permanent output of ore may be obtained. The recognized veins vary in width from about 10 inches up to about 5 or 6 feet, and some of them have been traced for lengths of several hundred feet and to depths of 100 to 400 feet.

The mines and prospects in this district were visited by me in 1888, 1889 and 1890, and some account of them has been given in the summary reports for 1888 and 1890, as well as in the Mineral Wealth of British Columbia.*

The vein-matter generally consists of white quartz, containing iron-pyrites, copper-pyrites, galena, blende and tetrahedrite, with a varying, but on the whole very satisfactory content of silver and gold. The following are assays of these ores made in the laboratory of the Survey. It is not always possible to attach these to the particular claims from which they were derived, the specimens having been obtained for the

*Annual Report, Geol. Surv. Can., vol. III. (N.S.), p. 69 B.

most part during the early stages of the prospecting and before my visit to the locality.*

Assays.

Locality.	Gold.	Silver.
	Ounces.	Ounces.
One of the Hepburn claims.....	0.759	406.574
Nicola Mining and Milling Co.....	0.729	104.721
Near Stump Lake.....	distinct trace.	20.339
" ".....	6.096	90.650
" ".....	0.732	15.094
" ".....	1.969	17.063

Ounces to the ton of 2,000 lbs.

Though scarcely any work has been done upon these deposits since 1890, partly in consequence of the general depression in mining matters, but in this instance also because of special difficulties of other kinds which have affected some of the companies chiefly concerned, there can, I believe, be no doubt that this district will ultimately become a mining centre of some little importance.

The following memoranda, referring to several of the principal properties and claims, are extracted from my notes, and may serve to give some idea of the general features of the deposits. No large-scale map or plan is yet in existence upon which the several claims can be definitely laid down.

The claims of the Nicola Mining Company and of the Star Mining Company are situated on and near Mineral Hill, between the wagon-road and the southern part of Stump Lake. Three principal openings, all shafts, have been made by the Nicola Mining and Milling Company as follows:—*Joshua Shaft*.—The lode here opened runs about N. 10° W. on the average, but turns rather more to the west when followed northward and somewhat more to the east in a southerly direction. It varies from about 10 inches to 5 feet in width and probably averages about 30 inches. It dips eastward near the outcrop, but becomes nearly vertical in depth. The rocks bordering the vein are considerably dolomitized, as is usually the case with veins in this district. The ore, like most of the others, shows iron- and copper-pyrites, galena and blende in a matrix of white quartz. Height of the head of the shaft above Stump Lake, about 420 feet. At the close of the year 1889, according to the report of the Minister of Mines for British Columbia,†

*Annual Report, Geol. Surv. Can., vol. III. (N.S.) pp. 38r and 40r.

†Annual Report of the Minister of Mines, British Columbia, 1889, p. 290.

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the main shaft was 400 feet deep. Air-shaft connecting with 100-foot level 85 feet. Total length of drifts at 100, 200 and 300-foot levels 745 feet. *Tubal Cain Shaft*.—The lode upon which this is sunk runs about N. 5° W. with an easterly dip at angles of from 60° to 70°. The ore resembles the last. In 1889 the main shaft had attained a depth of 220 feet. Air-shaft 40 feet. Total length of drifts and tunnels 1350 feet.* *King William Shaft*.—The deposit upon which this is sunk has not been traced far upon the surface, but is a strong lode in depth, with an average thickness of six feet, running about N. 10° W., with a very high easterly dip or nearly vertical. In 1889 the main shaft was 175 feet deep, air and other shafts 75 feet, total length of drifts 202 feet.†

The Star Mining Company had opened shafts upon two lodes, to the west of those above described. *Star Shaft*.—Is at a height of 200 feet or more above the lake, on a lode which runs about N. 5° W., and dips at an angle of 60° to the eastward, with a width of from 2 to 5 feet. The ore, which is of the usual character, is often distinctly ribboned, and is very little oxidized at a short distance below the surface. In 1888, this shaft had a depth slightly exceeding 100 feet, but was closed down in 1889 when the small crushing and concentrating mill which had been erected was burnt. *Planet Shaft*.—This was about 40 feet in depth only in 1888, and was closed at the same time with the last. The lode runs about N. 10° E., with an easterly dip, at an angle of about 70°. It has a width of 5 feet or more near the surface, but varied in this respect when followed down. The character of the ore here met with, differs somewhat from that seen in any other deposit of this vicinity. It has originally consisted of quartz with iron and copper-pyrites and some galena, but the vein has subsequently been re-opened, and brecciated, and a cement of brown-spar and chalcedony has been introduced. The sulphides have at the same time become much oxidized, and considerable quantities of blue and green copper carbonates have been formed. This subsequent action may probably be attributed to the period of Tertiary volcanic activity.

Mary Reynolds.—(J. Hepburn & Co.)—This is one of the "Hepburn Claims," and probably that to which the assay previously quoted refers. It is situated about two miles up the valley of Scott's Creek, on the north side. The lode is about 4 feet wide and very well defined, nearly vertical, and running N. 15° E. through a country-rock of porphyritic green diabase. It has been traced on the surface for 300 feet or more. According to the British Columbian Mining Report,

**Ibid.*, p. 290.†*Ibid.*, p. 291.

Dunsmuir.

there were at the end of 1889 three shafts on this vein, 100, 75 and 35 feet deep respectively, with 90 feet of drifts. *Dunsmuir*.—Situated about 500 feet west of the last, on a lode running about N. 5° W. and two feet or more in width, nearly vertical. Considerably decomposed where opened, but otherwise resembling the ore of the Mary Reynolds.

The following prospects are situated some distance to the south of the last two. They have been developed to a limited extent by sinking and costeaning upon the outcrops.

Various smaller openings.

British Empire.—A well defined lode about 5 feet wide, running N. 15° W., with a dip at angles of 70° to 80° to the eastward. Pyrites and galena are rather sparingly disseminated through the quartz.

Zeila.—This lode runs about N. 15° E., with a dip to the eastward of 45° at the surface, but becoming more nearly vertical at the bottom of a shaft 27 feet deep. Iron-pyrites is the most abundant visible metallic mineral, but galena and blende also occur. The wall-rock is a porphyritic green diabase with rather abundant pyrites crystals scattered through it.

Ardmore.—This claim adjoins the north end of the last. The lode runs here N. 38° W., and is called a 'cross lode.' It is about 15 inches wide and shows some pyrites and galena in openings about 200 feet apart.

Jennie Long.—Situated about half a mile south-east of Rockford post-office. This runs about N. 85° E., and had been opened to a depth of 66 feet at the time of my visit in 1888. The greatest width seen in the shaft was about 20 inches. It is somewhat irregular in dip, but not far from vertical.

A certain amount of prospecting work has been done on many other claims, but some of these it was not possible to visit in the time at my disposal, while in the case of others, no well-defined lodes had been developed by the work done.

Jamieson Creek.—

Lodes on Jamieson Creek.

The metalliferous veins found in this vicinity, fifteen miles up the North Thompson on the west side of the river, occur in a mass of greyish granite which here breaks through the Palaeozoic argillites (see p. 245 B). A number of claims have been taken up and a little surface work has been done on some of them, but I am unable to add much to the notes already given on these deposits in the Summary Report for 1888, as the locality was visited by me only in that year and no further work of any importance seems to have been done on any of the claims since.

The granite is considerably decomposed and in the vicinity of the veins is highly siliceous. The veins themselves are composed of quartz, sometimes holding fragments of granite and showing pyrites, with a little galena, blende, and tetrahedrite. It is probable that the date of origin of the veins is contemporaneous, or nearly so, with that of the intrusion of the granite mass, and that its silicification and decomposition happened concurrently with the segregation of the vein-quartz, which often forms irregular stringers characterizing certain zones of the rock.

The larger veins, so far as exposed, appear to run nearly due north-and-south. One of these, uncovered on the north side of the valley of the creek, about 700 feet above the stream, was found to be 10 feet thick. It had been traced for a distance of 200 feet, where a second small opening had been made which showed from 4 to 5 feet of vein-matter. In a second locality, on the face of the hill, near a log cabin built by the prospectors, the deposit opened up consisted of a system of irregular quartz-veins, some of which occasionally became several feet in thickness. On the top of the hill, about 70 yards north of the last locality, and possibly in continuation of the same deposit, some shallow costeaning pits showed as much as 6 feet of vein-stuff.

I was unable to identify the several claims by name, as no one connected with the work could be found at the time of my visit, but the generally high character of the ore is shown by the following assays, made in the laboratory of the Survey from the specimens received.*

Name of Claim.	Assays.	
	Gold.	Silver.
	oz.	oz.
Home Stake.....	1.108	34.243
Silver King.....	0.583	2.525
Silver Queen.....	0.758	28.992
Kamloops.....	0.700	25.200

Ounces to the ton of 2000 pounds.

The deposits met with in this locality certainly appear to deserve some further examination. It seems not improbable, that by operations partaking, in the first instance at least, more of the nature of quarrying than mining and not strictly confined to the wider veins, large quantities of ore of medium grade might here be obtained.

*Annual Report, Geol. Surv. Can., vol. IV. (N.S.), p. 60 n.

Cayoosh Creek.—

Lodes on Cayoosh Creek.

The source of the placer gold of this stream is evidently quite local, for coarse rough gold containing quartz has frequently been found in it. Mr. A. W. Smith, M.P.P., showed me, in 1889, several pieces of such gold mixed with quartz, one of which was estimated to contain several ounces of gold. The gangue in this case was about half quartz and half white calcite, through both of which the gold penetrated indifferently. Discoveries made subsequently to that of the placer mines, leave no room for doubt that the gold has originated from quartz-veins traversing the argillite-schists of the adjacent mountains, and a number of claims have been staked out on these. Specimens from several of them show visible gold, and many others yield gold in fine particles when roasted, crushed and washed. The best known and first discovered (1887) of the quartz properties upon this creek, is that named the *Bonanza*, in which several claims have been consolidated. Some very rich specimens of auriferous quartz have been obtained from this place, though the gold is more usually minutely and uniformly distributed through the quartz. A considerable amount of prospecting work has been done, but so far without leading to the establishment of any regular mining. The quartz-veins occur in the schistose series of rocks which forms considerable tongues and infolds in the granite of this part of the Coast Ranges and is referred to in greater detail elsewhere. (See p. 99 B.)

Bonanza claims.

The Bonanza claims are situated about seven miles up Cayoosh Creek from its mouth, on the steep mountain side on its right, or south bank. Numerous small quartz-veins here run with the strike of the black argillite-schists, generally about south-east by north-west, and usually following the dip of the rocks to the south-westward, but sometimes cutting across it. Few of these veins individually exceed a foot in thickness and some are much less. At the time of my visit, in 1889, the lowest work done, at about 390 feet above the creek, showed a face of say 30 feet in width, charged with broken and irregular small veins separated by crushed and displaced schists. Several tons of quartz had been taken out and piled here. Further up the very steep slope, (about 910 feet above the creek) a tunnel was being run in to intersect several quartz stringers seen at a greater elevation, from which rich specimens containing gold had been obtained. The length of the tunnel was then 160 feet, but was subsequently increased. Still further up (about 1410 feet above the creek) a shaft some 60 feet in depth had been sunk on a rather irregular vein, which in places showed 2 feet 5 inches of quartz. It would appear, that the best method of fairly testing this deposit, would be to endeavour to

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work of a of the zones characterized by numerous small quartz-veins, going back, at least in the first instance, from a natural face, and making no attempt to follow the veins by underground work. A small stamp-mill to treat the quartz obtained, would enable a trustworthy estimate to be made of the average quantity of gold likely to be secured on the large scale.

Other claims among the mountains of this vicinity were not visited, Other claims but from the specimens obtained and descriptions given, they appear closely to resemble the above, and the amount of free gold which several of them contain, is encouraging to the belief that some, at least, of them, will eventually be found to be profitable in regular mining operations.

Specimens from these claims assayed in the laboratory of the Survey, have yielded the following results.*

Name of Claim.	Assays.	
	Gold.	Silver.
	oz.	oz.
Bonanza	0.991	0.058
Crown Point	0.992	None.
Crown Point	0.722	None.

Ounces to the ton of 2000 pounds.

Big Slide Mine.—

The Big Slide mine, is situated on the bank of the Fraser, at the mouth of Kelley Stream. This stream falls very rapidly to the Fraser in a steep and rough gorge, and a good deal of labour was spent in constructing a tramway down this gorge to the mine. The mining operations were chiefly carried on in 1886, when a number of tunnels and drifts were made and a ten-stamp mill, with concentrator and chlorinating furnace was erected. All work was, however, suspended in 1887 and it has not since been resumed.

The rocks observed in this locality have already been noticed (p. 93 B). The vein upon which the work was done, is several feet in thickness and can be seen in the cliffs for a height of 300 or 400 feet at least. It runs with considerable regularity on a bearing of S. 45° E. with a north-eastward dip at an angle of about 70°. The material is quartz, containing iron-pyrites and a little copper-pyrites, and there appears to be no doubt that the ore can be obtained in considerable

* Annual Report, Geol. Surv. Can., vol IV. (N.S.), pp. 58 B, 59 B.

quantity. I was informed that difficulty had been found in saving the more valuable parts of the ore by the process of concentration employed, but whether or not this arose from unskilful work in the mill is not known. A specimen of the concentrates remaining in the mill at the time of my visit, in 1889, was subjected to assay in the laboratory of the Survey, with the following result:—

Assays of concentrates.	Gold.....	0.408 oz. to the ton of 2000 lbs.
	Silver.....	0.933 " "

The occurrence of the metalliferous vein at this place is pretty evidently in connection with the granitic mass of the vicinity (pp. 78 B, 242 B) having probably resulted from the hydrothermal action set up at the time of its intrusion. Further deposits of a similar kind may occur elsewhere along the same line.

OTHER MINERALS AND ORES.

Cinnabar on Copper Creek.

Mercury.—What may prove to be an important deposit of cinnabar, has lately been found in the vicinity of Copper Creek, Kamloops Lake, and several contiguous claims have been taken up on this, on the west side of the valley of the creek, near its mouth. The claims have, I believe, been combined in a single property, but the best looking deposit of ore occurs on the *Rosebush* claim, where a shaft about fifty feet deep, connecting below with a drift more than fifty feet long, had been opened. The height of this place is about 450 feet above the lake. Other small openings had been made in the same vicinity, as well as a second shaft, thirty-five feet deep, on the *Yellow Jacket* claim, about a quarter of a mile northward of the Rosebush.

Mode of occurrence.

The cinnabar occurs in irregular sparry veins, consisting chiefly of calcite and quartz, with some dolomite, traversing zones of a gray feldspathic and dolomitic rock which readily weathers to a yellowish colour. Both these zones and the contained veins, as a rule, run nearly magnetic north-and-south through the main rock of the hills, which is a dark greenish-black, Tertiary eruptive, containing pyroxene and olivine—but much decomposed. A considerable quantity of rich ore has been taken from the wider portions of the main vein opened on the Rosebush. Although the slopes of the hills are abrupt, they are almost everywhere covered with drift deposits, and much more work is necessary in order that the true value of the deposit may be ascertained. Exploratory trenching in an east-and-west direction would be the most economical method in the first instance. A little antimony sulphide (stibnite) is observable in some parts of the ore.

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Another claim, upon which very little work has been done, is the *Last Chance, No. 2*, situated on the east side of Copper Creek, near the junction of the Tertiary volcanic rocks with a small area of decomposed granite. Small quantities of cinnabar are found here, and some narrow seams of molybdenite also occur. In the adjacent granitic mass (p. 174 B), minute bright-red specks of cinnabar may also be detected, and it would appear that the extensive decomposition of the basic volcanic rocks of this region, by heated waters or steam, has led to the diffusion of a certain quantity of cinnabar through some parts of both classes of rocks, and to its concentration in some of the veins.

Decomposition of a similar character, has affected the rocks seen on the opposite side of Kamloops Lake, along the railway, to the east of the mouth of Cherry Bluff creek. No cinnabar has been observed here, but distinct traces of cinnabar are found in seams cutting some of the rocks at Six-mile Point, also on the south shore, but further to the west. I have also been informed that grains of cinnabar have been observed in washing for gold on Criss Creek, to the north.

These occurrences, taken together, indicate that search for cinnabar may be made with some prospect of success over a considerable area in this vicinity.*

Platinum.—The occurrence of minute scales of platinum, with gold on the Tranquille, has already been alluded to. It is also stated to have been found in the same manner on the Fraser, particularly at a place ten miles below Lillooet, but there are no indications of its existence in quantities of economic importance in this district.

Native Silver.—This metal is also occasionally found in the native state in gold-washings, particularly near Nicoamen on the Thompson, where pellets of considerable size are reported to have been discovered in 1858 and 1859.

Iron.—The occurrence of considerable quantities of magnetic iron-ore, and the general conditions under which it is found, in the rocks composing Cherry and Battle Bluffs on Kamloops Lake, are elsewhere mentioned (p. 157 B). The largest of these deposits which have been discovered, lie near the west end of Cherry Bluff. These were noted in my Report of 1877, and an assay by Dr. B. J. Harrington is there quoted which shows the ore to contain 66.83 per cent of metallic iron, with very little phosphorus or sulphur.†

*Since the above was written, further work has been done upon several of the claims, with results said to be satisfactory. Cinnabar has also lately been found in rocks about four miles further up the Copper Creek valley, on its west side.

†Report of Progress, Geol. Surv. Can., 1877-78, p. 118 B.

A property covering the principal known deposits near the west end of Cherry Bluff, with an area of 200 acres, was secured in 1889 by Mr. J. W. Mackay and named the *Glen Iron Mine*. The ore deposits have since been developed to some extent and worked intermittently, producing, according to the reports of the Minister of Mines of British Columbia, an aggregate quantity of 4700 tons, up to the close of the year 1894. The ore has been shipped to the coast and most of it to the State of Washington.

Note by Mr
McEvoy

In the autumn of 1892, the Glen Iron Mine was visited by Mr. McEvoy, who gives the following note on the deposits uncovered at that time.*

"The ore is magnetite throughout, with a slight mixture of calcite and feldspar in a few places, which, however, does not injure the ore for smelting. The following items were noted:—

"1. An opening a few feet from the railway, filling an irregular angular fissure from two to six feet in width.

"2. Three hundred feet south of last, a deposit of four feet of good ore, with five feet mixed ore and country-rock.

"3. Five hundred feet southward from last, a large deposit of four-hundred feet good ore, with ten feet of mixed.

"4. Thirty feet north-west of last, twelve feet ore

"a. West of last a vein three feet thick.

"6. South-west of last, numerous croppings of good ore undeveloped. At a low estimate ten per cent of the mass here is ore.

"7. North-east of No. 3, a vein four to ten feet thick. This is the principal source of output at present and is connected with the railway by an aerial tramway.

"All the veins run in an easterly and westerly direction, and are nearly vertical or dipping northward at high angles."

Mode of oc-
currence.

A short visit was again made to the mine by the writer in 1894, but no work was then in progress. The veins, or lenticular and alternating masses of ore, do not appear to be of the nature of a segregation from the enclosing eruptive rocks. The walls are often distinct, and the ore contains in some places brecciated fragments of the surrounding rocks, as well as imperfectly developed crystals of white feldspar, and occasionally is associated with much epidote. It is evident that a large quantity of good ore may easily be obtained at this place. A specimen of impure ore, consisting chiefly of a mixture of magnetite and

*Quoted from the Summary Report, Geol. Surv. Can., 1892.

hornblende, was examined for silver and gold in the laboratory of the Survey, but proved to contain only a trace of gold with 0.116 ounce of silver to the ton of 2000 lbs.*

Magnetic iron-ore is also known to occur near Watkinson's, about twenty-three miles above Lytton, on the Fraser River, where the vein is reported to be 20 feet in thickness.

Magnetite and iron-pyrites are found, apparently in considerable mass, in a ravine upon which a saw-mill was at one time situated, about half a mile below Nicoamen. The ore contains too much pyrites to be of value and on assay it proved to hold no gold or silver. Other occurrences of iron-ore.

Copper.—The vicinity of Copper Creek, Kamloops Lake, has been known to the Indians from time immemorial as a place of occurrence of native copper, but the precise locality had been lost. Native copper.

Specimens have, however, since been obtained from the Painted Bluffs, to the east of the creek, in which small grains and thin plates of copper appear. This occurs both in the mass of the rotten serpentinized rocks, and in dykes of now serpentinous trap cutting it. It is scarcely probable that deposits of a workable character will be found, but it was doubtless from such occurrences that the Indians derived their supply.

In 1888, a couple of claims which had been staked out on the east side of the creek about half a mile back from the lake, were visited. A small opening had been made which showed a shattered zone in the brown porphyritic trap of the vicinity, holding small quantities of copper-ores, largely decomposed. A specimen subjected to assay proved to contain no gold, and only 1.458 ounce of silver to the ton.† Since then, another claim named the *Tenderfoot*, has been taken up at the same place, and some prospecting work has been done, resulting in the discovery of a vein from twelve to fifteen inches thick, holding some quantity of bornite, in a gangue of dolomite, with some white felspar. The vein, so far as exposed, is a very irregular one, but the amount of work done upon it was quite inconsiderable. Bornite.

Near Watkinson's, Fraser River, about 23 miles above Lytton, gray copper (tetrahedrite) is reported to occur in considerable mass. A specimen assayed in the laboratory of the Survey, contained a trace only of gold and 5.833 ounces of silver to the ton of 2000 lbs. Other occurrences.

In association with magnetic iron-ore at the west end of Cherry Bluff, copper-pyrites occurs, but probably in small quantity.

* Annual Report, Geol. Surv. Can., vol. V. (N.S.), p. 58 B.

† Report of Progress, Geol. Surv. Can., 1877-78, p. 116 B.

‡ Annual Report, Geol. Surv. Can., vol. IV. (N.S.), p. 63 B.

At the Great Rock-slide, Thompson River, small quantities of copper-ores are found.

On the Thompson River, six miles below Spence's Bridge, rich specimens of purple copper-ore have been found in the drift, and at nine miles below the bridge a rough fragment of native copper, weighing several ounces, was found.

On the Fraser River, ten miles below Lillooet, and again on Eleven-mile Creek, pieces of native copper have been discovered.

In many of the ores of the district, notably in those of the vicinity of Stump Lake, copper-pyrites is an important constituent, but must be considered as subsidiary to the precious metals contained in these ores.

Lead.

Lead.—Galena occurs as a constituent of some of the ore-deposits, particularly in those of the vicinity of Stump Lake, but is nowhere known in the district in such quantity as to constitute a lead-ore by itself.

Antimony.

Antimony.—Stibnite occurs near Watkinson's, about 23 miles above Lytton, on the Fraser. The vein is reported to be about 14 inches wide, with quartz and calcite. The stibnite holds traces of gold and 2.187 ounces of silver to the ton of 2000 lbs.

Age of coals and lignites.

Coal and Lignite.—The deposits of coal and lignite found in the area of the Kamloops sheet, are confined to the rocks of Tertiary age, and the more important of them appear to belong to the older portion of the Tertiary which has been provisionally classified as Oligocene, though, as elsewhere mentioned, there appears to be a possibility that coals of Cretaceous age may yet be discovered (p. 66 B).

Causes of difference.

Some of the known fuels are true coals and yield firm cokes, while others are lignites, incapable of producing coherent cokes and containing a much larger percentage of water. This difference does not appear to depend so much upon the actual geological horizon at which the fuels are found, as upon the different degree of alteration to which the strata have been subjected after their deposition, in consequence of local causes, and perhaps to some extent upon the different composition of the vegetable material itself at the time of its inclusion. Thus the fuels met with on the North Thompson and in the lower or 'main' seam on the Nicola, both of which are supposed to be Oligocene, are coals, and that met with at Kamloops is also a coal, though included in the Miocene rocks, while the upper seams of the Nicola with that of Hat Creek (also believed to be Oligocene) are ordinary lignites.

Details already given.

The mode of occurrence, as well as the known or possible extent of the several deposits of coal and lignite, are so closely connected with the

stratigraphy of the formations in which they are found, that all details respecting them have been incorporated in foregoing pages of the Report.

The places of occurrence of coal upon the Nicola, near the mouth of the Coldwater, lie beyond the edge of the present map, but inasmuch as the extensions of the same basin enter the southern part of the map, some references to the known localities to the south are included in that part of the Report which deals with the Tertiary rocks of the Nicola Valley. Further particulars, with a section, may be found in the Report for 1877-78 (pp. 123 B, 127 B). Borings recently made in this vicinity, have afforded further evidence of the value of this coal-basin, and it is hoped that with the aid of these, and the better knowledge now gained of the Tertiary rocks as a whole, it may soon be possible to work out the structure of this basin in greater detail. It is the only locality in or near the Kamloops sheet in which a true coal of actually known workable thickness has yet been found.

Nicola-Coldwater field.

The following list of localities in which coals or lignites are known to occur, will serve as an index to the pages of the Report upon which a description of these occurrences may be found:—

References to localities.

North Thompson, near the Indian Reservation. *Coal*, p. 229 B.

Near Kamloops. *Coal*, p. 168 B.

Nicola Valley. *Coal and lignite*, p. 190 B.

Guichon Creek. *Lignite*, p. 192 B.

Hat Creek. *Lignite*, p. 207 B.

Bonaparte River, between C  che Creek and Ashcroft. *Lignite*, p. 213 B.

Thompson River, near Nicoamen. *Lignite*, p. 184 B.

Fraser River, below Lytton. *Lignite*, p. 188 B.

Red Point, Kamloops Lake. *Lignite*, p. 167 B.

Asbestos.—Small veins of chrysotile or serpentine asbestos, have been observed in or near some of the deposits of serpentine contained in the C  che Creek rocks, especially in the vicinity of the Fraser River, between Texas Creek and Bridge River, and in the southern base of Mount Soues, near Junction Valley. It is possible that workable deposits of asbestos may yet be found in these rocks, but the specimens so far obtained are too small and too short in the fibre to be of any economic value.

Asbestos.

Building and Ornamental Stones.—Nearly all the rocks met with in the region, are so much fractured and jointed as to be incapable

Structural materials.

of yielding good stone for masonry. There are no easily dressed free-stones, and the limestones are invariably greatly shattered. The granites, and some of the basaltic and other volcanic rocks of the Tertiary, are alone capable of affording good blocks of any considerable size, and of these only those which occur in the vicinity of the railway, or near to navigable waters, can be considered as possessing any great importance. The granites of the Coast Ranges are those best suited for purposes of construction, but these can be obtained most easily to the south of the present sheet.

The marbles, in which form the limestones are not seldom found, are too much shattered to be considered of value for polishing, and the same remark applies to the serpentines.

Brick clays.

Brick Clays.—Clays or silty deposits suitable for the manufacture of ordinary brick of fair quality, may be obtained from the alluvial deposits or lower benches of many of the larger valleys. The White Silts (p. 283 B) afford an unlimited supply of material from which fine, cream-coloured or fawn-coloured, hard bricks may be made, but the scarcity of fuel for burning bricks near the line of railway, detracts from the value of these silts for this purpose.

Lime.

Lime.—Limestones suitable for burning, are, as will be gathered from the map and from the foregoing descriptions of the rocks, extremely abundant, but to be readily utilized they must be situated on navigable waters or on the line of railway. The limestones most easily accessible from Kamloops and suitable for this purpose, are found near Venn's, seventeen miles up the North Thompson, on the west side; opposite the mouth of Campbell Creek, ten or eleven miles up the South Thompson from Kamloops, on the north side of the river, and near the mouth of Three-mile Creek, to the south of the railway. These and other localities nearest to the various settlements are indicated upon one of the maps accompanying this report.

China-stone
near Spatsum.

Opposite Spatsum station, on the west side of the Thompson, a mass of remarkably decomposed rocks occurs. So far as could be observed, the area of great decomposition is about half a mile long by quarter of a mile in width. The state of the rocks at this place is only a special case of the alteration which has affected a great belt of strata along this part of the river, as elsewhere noticed (pp. 79B, 115B). It is evidently related to the margin of the great granite mass on the east and to the faulting which has occurred here. The rocks have, in the first place, been thoroughly decomposed and pyritized, probably by the action of heated waters or steam, and subsequently more or less completely leached out by acid waters resulting from the oxidation of the pyrites. The soft resulting

material has been cut out in several steep gullies, where it appears as crumbling banks of red, yellow or white tints, upon which scarcely any vegetation grows. Some parts of these are almost purely siliceous, others consist of mixtures of quartz and kaolinite in varying proportions, often with a perceptible efflorescence of soluble salts of a styptic taste. The white and thoroughly leached rocks are those which have attracted attention as china-stone, and in these, kernels and veins of pure white gypsum sometimes occur. It is doubtful, however, whether any considerable quantity of china-stone could easily be quarried free from iron stains, while the china-clay or kaolinite could only be obtained in a pure state by the crushing and washing of the mass.

It is probable that parts of this deposit might advantageously be employed in the manufacture of fire-bricks. Specimens of the highly pyritous rock were assayed, but proved not to contain any gold. Possibly useful for fire-brick.

Agates and Chalcedony, are found in considerable abundance in some parts of the extensive tracts characterized by Tertiary volcanic rocks, particularly those occupied by the upper part of the Tertiary. The colours are usually pale, but many examples are prettily striped and banded. Green tints are not uncommon. The Nicoamen Plateau and that in the vicinity of Savona Mountain, with the neighbourhood of Dufferin Hill near Kamloops, are among the places where agates were found to be particularly numerous, but their occurrence and character depend on combinations of conditions which are always more or less local. *Hyalite* or Muller's glass, occurs in basaltic rocks near Hi-hium Lake (p. 220 B) and it is quite within the bounds of possibility that precious opal may be found in some of the volcanic rocks of the district (p. 233 B). Agates. Hyalite and opal.

Jade or Nephrite formerly much prized by the Indians for the manufacture of adzes, occurs as pebbles or small boulders along the Fraser and Thompson rivers. It has been observed by me in this form near Lytton and near Spence's Bridge, but has not yet been found in place. Worked fragments and adzes, or portions of adzes, may occasionally be found in the vicinity of old Indian burial places. I have described these occurrences elsewhere.* Three specimens of these nephrites have been analysed by Dr. B. J. Harrington.†

Mineral waters.—Many small saline springs occur in this district which are due merely to the accumulation of salts in the superficial Carbonated mineral water.

*Note on the Occurrence of Jade in British Columbia, Canadian Record of Science, vol. II., 1889, p. 364. Notes on the Shuswap People of British Columbia, Trans. Royal Soc. Can., vol. IX., sect. II., p. 18.

†Trans. Royal Soc. Can., vol. VIII. sect. IV., p. 51.

deposits of the drier valleys, and a number of the small pools and lakelets without outlet, are charged with similar salts, but the only known mineral spring of any possible importance, is situated on Maiden Creek, four or five miles west of Mundorf's. This is described by Mr. A. Bowman as being charged with carbonic acid. A qualitative analysis of its water has been made in the laboratory of the Survey.*

* Annual Report, Geol. Surv. Can., vol. II. (N.S.), p. 13 r.

APPENDIX I.

PETROGRAPHICAL CHARACTERS OF SOME ROCKS FROM THE AREA OF
THE KAMLOOPS MAP-SHEET, BRITISH COLUMBIA.

BY

W. F. FERRIER, B.A.Sc., F.G.S.,

Lithologist to the Geological Survey of Canada.

INTRODUCTORY NOTE.

The nomenclature adopted in the following descriptions is, in general, that of Rosenbusch, as given in the second edition of his "Massige Gesteine," but classification based on the age of the rocks has not been strictly adhered to.

Owing to the extreme alteration of some of the specimens submitted to me for examination, it has only been possible to refer these altered rocks to the general group in which they belong, without assigning them to their exact position in that group.

My acknowledgments are due to Dr F. D. Adams of McGill University for valuable suggestions and assistance received from him at various times during the progress of the work.

1. FELSPATHIC ACTINOLITE SCHIST.—Louis Creek, north side, two miles up. 167 (1888). Adams Lake series, Cambrian

This, in the hand specimen, is a fine-grained, greenish-gray, schistose rock, stained with iron oxide.

Under the microscope it is seen to consist principally of felspar; a little quartz; a green mineral in long needle-like crystals possessing inclined extinction, which is probably actinolite; epidote; and chlorite.

The felspar, like the quartz, occurs in aggregates of small clear grains and is only to be distinguished from it by the axial figure. Several of these were obtained, and showed clearly the revolving bar of a biaxial figure.

The felspar and quartz grains often form, together with epidote, little clear lenticular areas in the section.

Adams Lake
series—Cont.

The epidote is chiefly in irregular grains, occasionally in minute crystals showing sharply defined rhombic sections which are parallel to $\infty P\infty$ and bounded by the faces oP and $P\infty$.

2. GABBRO (?)—North Thompson River, east side, opposite mouth of Skull Creek. 193 (1890).

This rock, examined under the microscope, is seen to be much altered.

The augite originally present in it, is now almost entirely changed to hornblende, which, in its turn, is very largely altered to chlorite.

The felspar is all decomposed, and can now be traced only by outlines filled with various alteration products.

The whole section is so filled with chlorite, epidote, and sericite, that but little trace of the original structure of the rock can be seen, but it appears to have been of the nature of a gabbro, or possibly a diabase.

Dr. Dawson states that in the mass the rock is slightly schistose.

5.* DIABASE PORPHYRITE.—Two miles east of Poison Hill. 226 (1890).

Cliche Creek
formation.
Carboniferous

A rather coarse-grained rock, in which plagioclase and augite crystals, together with iron ore, occur porphyritically developed in a fine-grained groundmass. The rock is much altered, and the augite is nearly all converted into a fibrous, pale green hornblende, which, in its turn, is largely altered to chlorite. The latter mineral, together with other decomposition products and fine needle-shaped individuals of hornblende, is thickly scattered through the section. The plagioclase is well twinned, often possesses good form, and is much decomposed, being filled with little granules of zoisite, epidote, etc. The groundmass of the rock, where visible, apparently possesses a holocrystalline diabasic structure.

6. DIABASE PORPHYRITE (?).—Pass between Hat Creek and Oregon Jack's Creek, one mile east of Hat Creek. 239 (1889).

The section submitted to me was so thick that a satisfactory determination was impossible.

The rock is much altered and filled with chlorite, oxides of iron, etc. Both felspar and augite are exceedingly decomposed. The former occurs in lath-shaped individuals which show the twinning characteristic of plagioclase. There is apparently considerable fine-grained groundmass present, in which minute plagioclase crystals can be distinguished, but, owing to the thickness of the section and the extreme alteration of the rock, a determination of its true character could not be made.

* There are no specimens represented by numbers 3 & 4.

7. HARZBURGITE (SAXONITE).—As-kom' Mountain. 95 (1890).

Cáche Creek
formation—
Cont.

A coarse-grained, dark-green, serpentinous rock, showing imbedded enstatite with its characteristic pearly lustre.

The only minerals observed in the sections examined were olivine in an advanced stage of serpentinization, an altered orthorhombic pyroxene (enstatite), and iron oxides.

For such rocks, composed essentially of olivine and enstatite, Wadsworth proposed the name *Saxonite*.^{*} Posenbusch has used the name *Harzburgite* for the same group, and characterizes them as felspar-free olivine-norites.[†] The section was compared with sections of Harzburgite from Baste in the Harz and found to closely resemble them.

Dr. Dawson states that the specimen submitted to me was from one of many harder "cores" occurring in soft serpentinous schist at the locality.

It will readily be understood that as the serpentinization of the principal constituent, the olivine, proceeds, the olivine substance will eventually entirely disappear, giving rise to the soft serpentine rock in which, macroscopically, no trace of the original character of the rock would be perceivable.

The olivine occurs in irregular masses and shows in perfection its characteristic net-like alteration to serpentine, the strings of serpentine forming the net-work inclosing the yet unaltered portions of olivine. Hydrous iron oxides and magnetite have separated out during the process of alteration. The unaltered portion of the olivine is transparent, with marked relief, almost colourless, non-pleochroic, and exhibits brilliant interference colours.

The enstatite, like the olivine, occurs in broad, colourless, irregular masses, with parallel extinction, which are occasionally bent and twisted, and possess little or no pleochroism. It is largely altered to schiller-spar or bastite, the various stages of alteration being well shown in the sections. Some individuals exhibit merely a fine striation parallel to the vertical axis of the prism and at right angles to the partings. Others again show an alteration into a green serpentinous material, commencing in the cracks, especially those parallel to *OP*, and extending from them as threads and fibres parallel to the principal axis. The columnar structure often seen in enstatite was also observed, one individual in particular showing the long cylindrical hollows, sometimes filled with secondary ores, which are described by Rosenbusch[‡] as occurring in enstatite. As he has pointed out, it is

^{*} Lithological Studies, Cambridge, Mass., 1884.

[†] Massige Gesteine, 2nd Ed., 1887, pp. 264-271.

[‡] Die petrographisch wichtigen Mineralien, 2nd Ed., 1885, pp. 306-307.

Cliche Creek
formation—
Cont.

somewhat difficult at times to distinguish the long cavities from solid inclusions owing to the high index of refraction of the mineral which contains them. These tubular hollows are not continuous throughout the entire length of the prism. The change in the strength and character of the double refraction as the mineral changes from enstatite to bastite is most marked. In enstatite the double refraction is strong and positive, whilst in bastite it is much weaker and negative.

Only a very small specimen of this rock was available for examination, but it certainly belongs to the peridotite group and as the portion examined apparently corresponds closely to Harzburgite I have referred it to that type of the group.

8. AMPHIBOLITE.—Campbell's Creek, half a mile above Shumway Lake. 115 (1889).

The schistose structure of this rock, which consists essentially of a light-green fibrous hornblende and a triclinic felspar, is well shown under the microscope.

The hornblende occurs partly as irregular individuals elongated in the direction of the planes of foliation, and partly as small acicular crystals, having a similar general parallelism, distributed through the plagioclase. It is pleochroic in green and yellow tints, the pleochroism being more marked in the acicular crystals (actinolite?) than in the larger individuals.

The plagioclase also occurs in the same way in irregular individuals of comparatively large size, showing well-marked twinning striation, and as a fine mosaic between these larger individuals and the hornblende. That this mosaic is secondary is shown by the fact that it contains numerous minute needles of secondary hornblende.

No quartz could be determined with certainty, though a little is doubtless present.

Epidote, chlorite, iron ore, and pyrite also occur in the section, which is much stained with hydrous oxides of iron, and fine scales of a brown mica were seen in the hand specimen but were not detected in the section.

Similar schists have been shown by many observers to result from the shearing of diorites and diabases*, and it is quite likely that the rock now under consideration may have had such an origin. Teall

* See Lehmann, Untersuchungen über die Entstehung der Altkrystallinischen Schiefergesteine, Bonn, 1884, p. 190.

G. H. Williams, Bull. U. S. Geol. Surv., No. 62, 1890.

Teall, Q. J. G. S., xli., 1893, p. 133; British Petrography, 1888, pp. 198 and 244.

Hatch, Mem. Geol. Survey, Explanation of Sheets, 138, 139, 11. land, p. 49.

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points out that quartz appears to be rare in those schists which can be definitely proved to have originated in consequence of the metamorphism of igneous rocks. Cache Creek formation—
Cont.

(Compare Nos. 9, 10, 1, and 16).

9. AMPHIBOLITE.—Campbell Creek, one half mile below Shumway Lake. 111 (1889).

This section is almost identical in its general features with No. 8. The iron ore, however, is nearly all altered to leucoxene, which occurs in great abundance in translucent irregular forms, sometimes rudely rhombic in outline, having a granular structure and a grayish colour. The individual granules, examined with a high power, show a high index of refraction and brilliant interference colours. The section was compared with those described by Dr. Adams from the Eastern Townships of Quebec as containing a similar mineral,* and it was at once seen that the two minerals are the same, and undoubtedly leucoxene, a form of titanite or sphene derived from the alteration of titanite iron ore. Finely divided plagioclase was recognized in the groundmass.

This is another of those altered rocks which in all probability have been derived from basic igneous rocks by contact and dynamic metamorphism.

The hornblende, as in No. 8, possesses a fibrous structure and has every appearance of secondary origin.

Phillips has well described the passage from the original eruptive to similar schistose rocks, entirely devoid of the characteristics of the original rock, in occurrences at various localities in the west of England.† Teall also describes in detail the variations in structure and composition in "greenstones" from England,‡ stating that the most important secondary structural characteristics are those which depend on the development of foliation, and that the most important secondary characters in composition depend upon the development of chlorite, or some form of hornblende, at the expense of the original augite; of leucoxene, and ultimately granular sphene, or rutile, at the expense of the titaniferous iron ore; and of water-clear secondary feldspar (albite?) and other substances, at the expense of the original plagioclase.

From a perusal of the above remarks it will be seen how closely they apply to those rocks described by Dr. Adams in the report already

* Report of Progress, Geol. Surv. Can., 1880-81-82. Appendix to Dr. Selwyn's Report, p. 16a.

† Q. J. G. S., vol. XXXII., 1876, p. 155; vol. XXXIV., 1878, p. 471.

‡ British Petrography, 1888, pp. 230, 234, 235.

Cache Creek
formation—
Cont.

referred to (see p. 353 of the present report, foot-note), and to the ones from British Columbia now under consideration.

10. AMPHIBOLITE.—Campbell Creek, one mile below Shumway Lake. 110 (1889).

This specimen is of a rather finer grain than Nos. 8 and 9, and the section shows it to contain a large quantity of a brown mica in addition to the hornblende, but its general features are the same as in those two rocks.

The groundmass, as before, consists of a fine mosaic of water-clear grains of feldspar, probably albite, embedded in which are numerous little needles of actinolite, proving its secondary character. Some of the feldspar grains are striated.

The hornblende occurs in irregular fibrous individuals, and also in the form of fine needle-like crystals of actinolite. It commonly shows an alteration to chlorite.

Leucoxene, in irregular bunches of fine granules with a very high index of refraction, is abundant. Quartz was not determined with certainty, as satisfactory axial figures could not be obtained.

The brown mica is very abundant in the section, being nearly equal in quantity to the hornblende with which it is intimately associated. It is reddish-brown in colour, and occurs in small irregular folia, which, in sections at right angles to the basal plane, are strongly dichroic. Its interference colours are the same as in biotite, to which species it is undoubtedly closely related, if not identical with it.

The rock is without doubt of the same origin as the similar ones already described.

11. AMPHIBOLITE.—Moore Creek, west side, four miles above Nicola Lake. 264 (1890).

This rock, whilst presenting the general features of those of the same class already described, differs from them in some respects. It is apparently less foliated, and its matrix, whilst showing the usual clear feldspar mosaic, also contains numerous larger fragments of plagioclase, in some instances with crystalline form. Quartz is also present, and epidote is exceedingly abundant, in irregular, strongly pleochroic grains, exhibiting brilliant interference colours. Irregular bunches of finely granular leucoxene, accompanied by some ilmenite, are thickly scattered through the section. There are also numerous crystals of pyrite, of a good size, and showing alteration to limonite. The hornblende is decidedly uraltic in appearance and largely altered

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12. AMPHIBOLITE.—Nicola Lake. 2

The rock is
probably result

13. TUFF?—(1877).

A dark-gray,
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14. TUFF?—H

A black, rusty
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The remarks made
only that it is not
stituents, and is
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to chlorite. In some instances forms resembling augite were seen. Only a very few small scales of brown are present.

CACHE CREEK
FORMATION
Cont.

12. AMPHIBOLITE.—Moore Creek, west side, four miles above Nicola Lake. 265 (1890).

The rock is the same as No. 11 in its general characters, and has probably resulted from the alteration of some basic eruptive.

13. TUFF?—Half a mile north-west of Shumway Lake. 2A (1877).

A dark-gray, fine-grained, compact rock, which has evidently been greatly crushed and shattered. It is laminated in structure, this lamination being especially well seen on the weathered surfaces. The specimen is highly calcareous, effervescing freely with dilute hydrochloric acid, and is traversed in all directions by cracks filled with crystalline calcite.

The microscope shows the extreme alteration of the rock, which now consists of an exceedingly fine-grained mosaic of re-crystallized interlocking grains, apparently feldspathic, in which are numerous clear lenticular patches and strings of quartz, which, between crossed nichols, also exhibit a mosaic structure.

Numerous little scales of a reddish-brown, strongly pleochroic biotite are scattered through the sections, which are filled with calcite in irregular patches and also filling-in the numerous cracks and partings. Scales of sericite are also abundant.

A large quantity of a black nondescript material is present, in lenticular patches and irregular strings with a general parallel arrangement, which marks out clearly the laminated structure of the rock in the thin section. Some irregular, angular patches, resembling embedded fragments, suggest that this rock may possibly be a highly altered tuff or ash-rock, but, owing to its very bad state of preservation, it is hard to arrive at any definite conclusion as to its origin.

14. TUFF?—Half a mile north-west of Shumway Lake. 2B (1877).

A black, rusty weathering, fine-grained, thinly laminated rock, which, in thin splinters before the blowpipe, fuses readily to a brownish, glassy slag, but does not alter greatly in colour before fusion. It contains carbonates, effervescing slightly with dilute acid, but only in spots.

The remarks made regarding No. 13 apply in general to this rock, only that it is not nearly so calcareous, contains more micaceous constituents, and is more evenly laminated. The angular fragments are also more abundant and much more distinct. Large angular fragments

Câche Creek
formation—
Cont.

of felspar were observed lying across the planes of lamination, around which the other constituents bend in such a manner as to mimic "flow-structure."

Scales of a brownish micaceous mineral occur, which are frequently aggregated into rosettes throughout the rock.

As in the case of No. 13 numerous little granulated areas of quartz were observed.

15. CLASTIC ROCK (TUFF?).—North of Douglas Lake granite mass. 342 (1877).

A fine-grained, thinly laminated, dark-gray, almost black, rusty weathering rock, in which the planes of bedding, indicated by layers of different coloured materials, are inclined at an angle of about 65° to the planes of lamination. The microscope shows it to be made up of layers of light and dark material, very finely granular, and mainly fclspathic, showing evidences of partial re-crystallization, and containing many small angular fragments of felspar and quartz, scales of sericite, grains of calcite, and a large quantity of a strongly pleochroic brown mica, probably secondary, the folia of which have a general parallel arrangement corresponding to the plane of lamination in the rock.

The whole section is much stained by hydrous oxides of iron, often aggregated into patches of considerable size.

The light-coloured layers in the rock contain what appear to be composite fragments of some foliated clastic rock, the foliation of these being often at a considerable angle to that of the main mass of the rock.

16. CHLORITIC AND EPIDOTIC SCHIST.—Cayoosh Creek, near Bonanza Mine. 278 (1889)

The matrix is very fine-grained, consisting of quartz and felspar, through which the chlorite and sericite run in long, continuous, irregular folia. Epidote is very abundant in irregular granules, possessing marked pleochroism, yellow to colourless, and brilliant interference colours. Numerous little lenticular patches and bands occur throughout the section, which are chiefly composed of a hydro-mica (sericite?), with irregular crushed fragments of quartz and felspar, showing very uneven extinction, embedded in it. These fragments are larger than those in the main mass of the section.

The micaceous constituents of the rock show a well-defined parallelism.

17. PORPHYROID (SCHISTOSE).—Between Seton Lake and Cayoosh Creek. 276 (1889).

This consists of an exceedingly fine-grained felsite-like groundmass with a schistose structure, composed of quartz, orthoclase, and plagioclase.

much sericitic and chloritic material, and also large quantities of a black, opaque, decomposition product, which marks out clearly the lines of wavy foliation in the rock. Câche Creek formation—*Cont.*

Much hydrous oxide of iron is also present, giving a rusty stain to the rock. Occasional larger grains of quartz and felspar are to be seen, and the section is traversed by numerous little veins of quartz.

The planes of schistosity are very wavy and contorted, and the specimen resembles the class of rocks to which the name *porphyroid* has been given, and which were first described from Thuringia, the Harz, the Taunus, and the Ardennes, where they occur associated with Palæozoic strata. They may be characterized as rocks composed of a felsite-like groundmass which has assumed a more or less schistose structure from the development of micaceous (sericitic) scales, and which contain porphyritically scattered crystals of felspar and quartz. As pointed out by Teall,* many of them are distinguished from the porphyries merely by the presence of wavy planes occupied by sericite or some other micaceous mineral, and that by an increase in the number of these planes, and a corresponding increase in the micaceous mineral, they pass into schistose porphyroids, and finally into sericite schists. They shade into llellinta-like rocks by the disappearance of the porphyritic constituents and of the schistose structure.

He points out that the typical porphyroids of the Ardennes bear the same relation to quartz porphyries that the "schistose greenstones" do to dolerites, and are for the most part acid rocks that have been affected by dynamic metamorphism.

18. SAUSSURITIC ROCK.—Cayoosh Creek, near Bonanza Mine. 277 (1889).

The hand specimen is a light-green, tough, compact, and somewhat schistose rock. Under the microscope the section presents the appearance of a confused felted aggregate of chlorite, zoisite, epidote, calcite, a pale green mineral in needle-like crystals resembling actinolite, and occasional patches of more or less altered felspar. Little bands filled with epidote and zoisite grains, and scales of sericite, run through the main mass. It is probably the result of metamorphism of the basic felspar of a gabbro or diabase, a change common in rocks affected by regional metamorphism.†

The name *saussurite* was originally applied by De Saussure to a similar aggregate occurring in the rock named *euphotide* by Häüy. De Saussure

* British Petrography, 1888, pp. 294, 337, 338.

† See Rosenbusch, *Massige Gesteine*, 2nd Ed., 1887, pp. 163-164; also Hagge, *Mikroskopische Untersuchungen über Gabbro*, etc., Kiel, 1871, p. 51.

Cliche Creek
formation—
Cont.

believed the substance to be a definite mineral, but subsequent investigation proved its composite character.* Cathrein thoroughly investigated the substance chemically and microscopically, and his conclusions, summed up by Teall, are:—that it is not a mineral, but a mixture, as above; that in its chemical composition it, in general, resembles the soda lime felspars; that it is produced by the metamorphism of the felspar through interchange of silica and alkalies, with lime, iron, and water; and that epidote is produced in a similar manner to the zoisite, only that more iron is taken up.†

In the specimen examined the zoisite occurs in irregular grains and crystals, exhibiting its characteristic pale blue interference colours. Calcite is abundant. The few fragments of felspar observed, though much altered, show indistinctly the twinning of plagioclase.

The section being thick, but little of the matrix could be made out, but here and there a fine-grained glassy mosaic was observed, which is probably composed of felspar (albite?).

19. DIABASE TUFF.—Ridge east of Paul's Peak, near Kamloops. 102 (1889).

A rather fine-grained fragmental rock, made up of fragments of augite, plagioclase, titanite iron ore accompanied by leucoxene, hydrous iron oxides, chlorite, and fragments of what is apparently diabase porphyrite.

One of these rock fragments, though much altered, shows large, well crystallized plagioclases, a large augite crystal, and a grain of ilmenite accompanied by leucoxene, embedded in a fine-grained ground-mass. Other fragments are of a much finer grain.

The augite, as a rule, is quite fresh, and often possesses sharp crystal form. Occasionally it shows alteration to a chloritic substance. It is yellowish in colour, clear, and exhibits the usual cleavages and other physical characters of the species. A few crystals were observed polysynthetically twinned according to $\infty P\infty$. The extinction angle on the clinopinacoid in one instance was found to be 44° .

The plagioclases, like the augites, often have sharply defined crystallographic boundaries. They are greatly decomposed, and present a very cloudy appearance, the twinning structure being almost obliterated. Zonal structure was noticed in a few of them.

* See Cathrein, Ueber Saussurit, Z. K., Band VII, 1883, p. 234; also Teall, British Petrography, 1888, pp. 148-155.

† Since the above was written Mr. A. E. Barlow has published a paper, in which the structure of Saussurite is minutely described. See On some Dykes containing Huronite, Ottawa Naturalist, vol. IX., pp. 25-47.

20. DIABASE TUFF.—Lower part of Cayoosh Creek. 285 (1889). Cache Creek formation—*Cont.*

A fine-grained, greenish-gray, somewhat schistose rock, whose clastic structure is at once seen under the microscope. It is made up of irregular fragments of plagioclase, quartz, augite, ilmenite with leucoxene, and numerous rock fragments, embedded in a fine-grained matrix filled with chlorite and epidote.

Most of the grains are plagioclase, generally much altered to calcite, kaolin, and other products of decomposition.

Some of the rock fragments referred to above, consist of broad crystals of plagioclase, with fibrous much altered hornblende, probably derived from pyroxene, and resemble gabbros; others are fine to medium-grained, with diabasic structure; whilst others again are very fine-grained and felsitic, resembling devitrified glassy eruptives. They are all much decomposed.

21. CHERT, OR CHERTY QUARTZITE.—Hills north of Medicine Creek, near Hat Creek. 259 (1889).

This is a very fine-grained, compact, siliceous rock, which, in the section examined, is cut by numerous little veins of quartz. The texture of the rock is too fine to admit of a satisfactory determination of the optical character of the separate grains or concretions of silica, but the spherulitic interference cross given by the concretions, and their general appearance, indicate that they are probably composed of chalcedonic quartz.

Dr. Dawson has pointed out *that these cherts, or cherty quartzites, have probably been produced by the action of thermal waters which silicified the accompanying rocks, and suggests that some of them may have originally been argillites.

The section examined shows many nondescript impurities, including considerable quantities of a blackish carbonaceous-looking material, and hydrous oxides of iron.

22. DIABASE PORPHYRITE.—North of Kamloops Lake, one mile and a half east of Red Point. 164 (1890). Nicola formation. Triassic.

Under the microscope this rock is seen to consist essentially of large, well defined crystals of plagioclase, augite, and iron ore, embedded in a fine-grained holocrystalline groundmass of the same materials. Epidote, calcite, pyrite, a little chlorite, and hydrous oxides of iron are also present.

* Report of Progress, Geol. Surv. Can., 1877-78, p. 92 B.

Nicola formation—*Cont.*

The rock is considerably altered. The plagioclase is cloudy and filled with decomposition products. It occurs in large, sharply-defined, well-striated individuals, and also in smaller lath-shaped crystals in the groundmass. The augite exhibits large, sharp, crystal forms, which are generally octagonal in outline and often beautifully symmetrical, both pinacoids being well developed. It is much altered to epidote, calcite, etc. The iron ore (ilmenite) is abundant and accompanied by its alteration product, leucoxene. Epidote occurs throughout the section in large quantity as the result of the decomposition of the feldspar and augite. It is in the form of coarse and fine granules, and also in radiating bunches of small prisms which sometimes exhibit aggregate polarization, with a well-defined interference cross. Its pleochroism is marked, yellow to colourless. The rock is a typical diabase porphyrite.

23. DIABASE PORPHYRITE.—Hills south of Nicola Lake. 140 (1889).

The section submitted for examination was very thick, but the rock appears to be a diabase porphyrite of the ordinary type. It is in an advanced stage of alteration, and consequently its structure, in the thin section, is much obscured by the products of decomposition.

The augite occurs in large, well defined, eight-sided sections, many of which show most beautifully its uralitization (the alteration from augite to hornblende), the central cores of the crystals consisting of unaltered augite with its characteristic cleavage, and the margins of a pale green fibrous hornblende.

Numerous radiating bundles of needle-like crystals of some zeolitic mineral occur throughout the section, probably derived from the alteration of the feldspar.

Several little clear areas were noticed, which, between crossed nichols, are seen to be made up of grains of some mineral having a finely fibrous, radiated structure, and showing an interference cross. These are probably composed of chalcedonic quartz.

24. DIABASE PORPHYRITE (AMYGDALOIDAL).—One mile south of Meadow Creek, $2\frac{1}{2}$ miles above Greenstone Creek. 18 (1890).

A rather fine-grained, distinctly amygdaloidal, chocolate-brown rock, spotted with white, due to the calcite filling of the amygdules.

It consists essentially of porphyritic crystals of augite and plagioclase feldspar, embedded in a fine-grained groundmass of the same materials. This groundmass is so impregnated with products of decomposition, such as hydrous iron oxides, epidote, calcite, and chlorite, as to render it impossible to determine with certainty whether glassy

matter is present or not, but the flow-structure, observable in portions of the section, would lead one to believe that it is. Nicola formation—Cont.

Large amygdules now filled with calcite, yellow, strongly pleochroic epidote, and zeolites, are thickly distributed through the rock. Some of these amygdules, filled as they are with radiated bunches of brilliantly polarizing epidote, are most beautiful objects under the microscope. The portions of the rock immediately surrounding the amygdules are stained a very deep brown, presumably by hydrous oxides of iron.

Alteration of the porphyritic crystals of plagioclase has proceeded to such an extent as to almost entirely obliterate their twinned structure. The porphyritic augites are also much altered to chlorite, epidote and calcite.

As seen in the section, the groundmass of the rock is made up of slender, lath-shaped sections of plagioclase, and irregular grains of augite, and possesses an apparently hypocrySTALLINE structure, although, as above mentioned, the presence of glassy matter cannot be positively proved. A little secondary quartz was observed, and the specimen examined is traversed by numerous little cracks filled with crystalline calcite.

25. DIABASE PORPHYRITE.—South shore of Kamloops Lake, opposite Copper Creek. 320 (1877).

A very poor section. The rock presents no unusual features. It contains a few included fragments.

26. PORPHYRITE.—Joshua Mine, Stump Lake. 102 (1888).

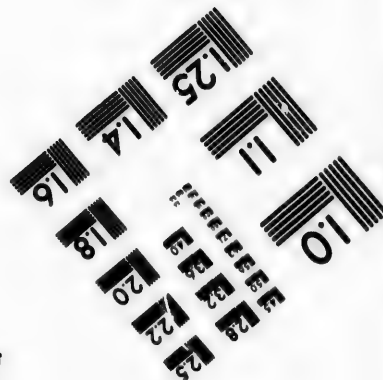
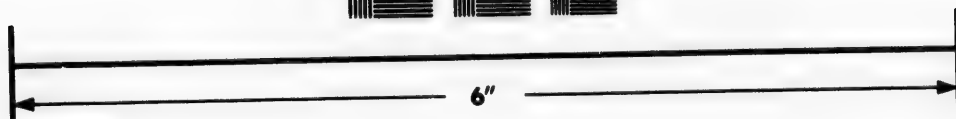
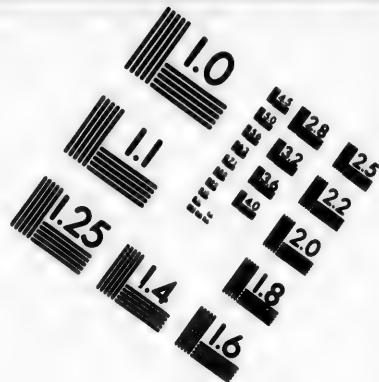
This is a soft, exceedingly decomposed, highly calcareous rock, which exhibits, in sections, a confused mass of chloritic and sericitic or talcose material, with a large quantity of carbonates.

More or less indistinct outlines of the original porphyritic felspar crystals are still visible, but now filled with calcite and other alteration products.

The large amount of carbonates in the rock renders it probable that the predominating felspar was a plagioclase. Some of these carbonates present good crystal form, showing sharply defined rhombic sections, and may be dolomite. The absorption in these crystals is marked, with $O > E$.

27. MELAPHYRE (AMYGDALOIDAL).—One-quarter mile south of Meadow Creek, $2\frac{1}{2}$ miles below Greenstone Creek. 22 (1890).

This rock, whilst resembling in a general way No. 24, is coarse-grained, and the phenocrysts of augite are larger, as are also the amygdules. Olivine is also one of its constituent minerals.



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Nicola formation—*Cont.*

The amygdulæ, mostly rudely spherical in form, occasionally measure $\frac{3}{8}$ ths of an inch in diameter and are filled with zeolites, calcite, sericite, chlorite, and epidote.

The colour of the matrix is about the same as in No. 24, namely a dark chocolate-brown.

The plagioclase phenocrysts are comparatively few in number and greatly decomposed.

Those of augite on the other hand are remarkably fresh, and occur chiefly in sharply defined, octagonal sections, which are approximately at right angles to the *c*-axis, frequently show polysynthetic twinning, a zonal structure, and contain grains of magnetite.

Numerous porphyritic skeleton crystal forms, filled with hydrous iron oxides, etc., which accompany the augites, in all probability represent a highly ferruginous olivine originally present in the rock. These ferruginous olivines (hyalosiderite, fayalite, etc.) are very characteristic of the porphyritic eruptive rocks.

28. MELAPHYRE. (?)—Hills south of Nicola Lake, near McDonald or Quilchenna Creek. 139 (1889).

A fine-grained, compact, dark-green rock, much fissured, and containing porphyritic crystals of augite.

The section is filled with epidote, calcite, chlorite, serpentine, and other decomposition products.

Blotches of serpentine, calcite, and iron ore, representing what was probably originally olivine, occur side by side with comparatively unaltered augite.

The plagioclase is almost entirely decomposed. Well-twinned, comparatively fresh, crystals of augite are abundant. The different states of preservation of these two minerals may be due to the composition of water acting as the decomposing agent, permitting it to act more powerfully on the plagioclase than on the augite.

A small fissure, filled with epidote, passes through the section and traverses a large augite crystal, half of which is faulted considerably to one side.

29. GABBRO, WITH DIABASIC STRUCTURE. North of Kamloops Lake, one mile and a half east of Red Point. 163 (1890).

This is a considerably altered eruptive, which owes its red colour to iron oxides derived from the pyrite which is plentifully scattered through the section. The rock is composed chiefly of plagioclase, augite, epidote, and pyrite, and has somewhat the structure of a gabbro, that is, there are considerable areas of plagioclase comparatively free from

basilicates, so that it does not possess the typical ophitic structure characteristic of a diabase. The habit of the plagioclase is also more that of gabbro plagioclases than of those occurring in diabase.

Nicola formation—Cont.

A few porphyritic crystals of the plagioclase and augite are scattered through the section. No quartz was detected.

In a few instances what appear to be fragments of some eruptive are embedded in the mass of the rock.

30. PROTEROBASE OR EPIDIORITE. Road north of Trapp Lake. 120 (1889).

In the hand specimen this is a mottled green and whitish, rather coarse-grained, gneissic rock, whose foliation is not of the even type seen in a typical schist, but is more like "flaser" structure, the minerals occurring in more or less elongated streaks.

In the thin section the rock is seen to be composed chiefly of plagioclase, hornblende, augite, biotite, and a little quartz, with epidote, chlorite, titanite, apatite, pyrite, sericite, zeolites, and hydrous iron oxides, as accessory constituents.

The plagioclase occurs in the form of coarse-grained individuals, with finer crushed saussuritic material between them. The majority of them are well-striated, full of inclusions, and exhibit very uneven extinction. Twinning according to both albite and pericline laws is often seen in the same individual. The plagioclase is considerably altered, sometimes giving rise to the formation of little radiating bundles of fine needle-like crystals of some zeolitic mineral. Evidences of pressure are numerous, and the twinning lamellae are often much bent.

The hornblende occurs in large, irregular, strongly pleochroic individuals of green and brown colours, exhibiting good cleavages; also in the form of actinolite penetrating the felspar. The same individual will often have a brown centre with an outer rim of a green colour. Although much of the hornblende has a fibrous structure, yet at first sight the greater part of it appears to be much more compact than in the case of the schistose hornblende rocks previously described, and not so uralitic in appearance. A careful examination of the section, however, shows that augite still survives in individuals which exhibit its characteristic cleavage, and it moreover forms "cores" in the hornblende, the latter mineral being clearly derived from its alteration.

A brown mica, of the variety common in altered rocks, is present in small quantity.

My interpretation of the rock is, that it is a diabase in which the original augite has been altered, and the ophitic structure almost entirely destroyed by contact and dynamic metamorphism. To such

Nicola formation—Cont.

rocks Gumbel applied the term *proterobase*.^{*} Some of these, and similar ones from other localities, have been shown to be normal diabases altered by the two kinds of metamorphism, contact and dynamic.[†]

Where the augite has entirely disappeared or is present in only very small quantities, Gumbel applied the term *epidiorite*.

It should be stated here that no sharp lines can be drawn between diabase, proterobase, and epidiorite. The transitions are gradual, and often these three types are furnished by the same rock mass. The view taken of the origin of this particular rock from its microscopical examination is borne out by Dr. Dawson's observations in the field. He regards it as a Triassic diabase which has been altered by contact with a granitic mass. Lossen has shown that the proterobase from Winzenburg, in the Harz, described by Rosenbusch as typical of that class, is a normal diabase altered by contact with granite.

31. DIABASE TUFF.—Near the 232nd mile-post, Canadian Pacific Railway, south shore of Kamloops Lake. 318 (1877).

This is a rather coarse-grained elastic rock, made up of fragments and crystals of plagioclase, a pale yellowish augite, and iron ore, together with numerous fragments of what is apparently diabase porphyrite.

Much of both the plagioclase and augite show sharp crystallographic boundaries, the augite individuals being often of a large size. Both minerals are much altered, the plagioclase, as usual, more so than the augite.

The section is full of pyrite and various alteration products.

The included rock fragments show sharply defined, large crystals of augite and plagioclase, together with iron ore, porphyritically developed in a fine-grained diabasic-granular groundmass, in some instances filled with opaque decomposition products.

A large augite crystal, embedded in one of the fragments, shows in a most beautiful manner the so-called "hour-glass structure," exhibiting four fields in parallel polarized light, alternate fields displaying similar colors. The direction of maximum extinction is the same in the alternate fields, but differs in the different pairs. Subsequent filling-in of the spaces in a skeleton crystal of augite is supposed to account for

^{*} Die paläolithischen Eruptiv-gesteine des Fichtelgebirges, Munich, 1874, p. 9.

See also Rosenbusch, *Massige Gesteine* 2nd ed., 1887, pp. 206-210.

[†] See Allport *On the Metamorphic Rocks Surrounding the Land's End Mass of Granite*, Q. J. G. S., 1876, XXXII., p. 407.

Lossen in *Sitz. d. Ges. natur. Freunde*, Berlin, 1885, p. 22.
Liebe, *Übersicht über der Schichten-aufbau Ostthuringens*. Abhand. Z. geo. Specialkarte v. Preussen u. d. Thüring. Staaten. Bd. V., Hft. 4.

this structure.* Zonal structure also is seen in many of the augites in the section, the zones sometimes not being parallel to the boundaries of the crystal. Nicola formation—Cont.

32. **DIABASE TUFF.**—North of Kamloops Lake, two miles and three-quarters east of Red Point, and behind Battle Bluff. 165 (1890).

This rock, under the microscope, is seen to be clastic in its origin. It is composed of fragments of plagioclase felspar, augite, pyrite, zircons, etc., cemented together by a highly calcareous and ferruginous matrix which is proportionately small in quantity. Numerous fragments of tuffaceous rock are also present along with the fragments of simple minerals. In its constituent minerals it bears a close resemblance to No. 29 and is just such a tuff as one might expect to find accompanying a rock of that character.

The pyrite is very abundant, and by its oxidation has stained the rock a deep reddish-brown.

33. **DIABASE TUFF.**—Hills south of Nicola Lake. 138 (1889).

A dark-green, fine-grained rock, showing various irregular mineral fragments embedded in it. The section shows this to be a typical diabase tuff, holding fragments of diabase porphyrite.

This clastic rock is made up of irregular fragments of plagioclase, augite, iron ore, and the rock fragments referred to above.

Both plagioclase and augite are much decomposed, and the section has much epidote and chlorite scattered through it.

The included rock fragments possess a very fine-grained matrix, in which well defined crystals of plagioclase, augite, and iron ore are porphyritically developed.

The augite occurs in octagonal sections, is often well twinned, and in many of the fragments quite fresh, in marked contrast with the plagioclase, which is nearly always greatly decomposed.

34. **DIABASE TUFF.**—Peterson Creek, south of Coal Hill. 1 (1890).

A fine-grained, compact, dark-green, clastic rock, composed chiefly of irregular grains and crystals of plagioclase felspar, augite, and iron ore, together with fragments of a greatly decomposed porphyritic rock, all cemented together by finer grained material of the same kind.

The specimen is much decomposed and highly calcareous.

Both plagioclase and augite are considerably altered, the former to calcite, kaolin, etc., the latter to chlorite, epidote and magnetite.

* See L. Van Werveke in Neues Jahrbuch für Mineralogie, Geologie, und Paläontologie, Stuttgart, 1879, pp. 482 and 822.

Nicola formation—Cont.

35. VOLCANIC BRECCIA OR ASH ROCK.—One mile east of Penny's Station, Canadian Pacific Railway. A (1888).

This is a clastic rock composed of irregular fragments of felspar, augite, and iron ore, together with various more or less rounded rock fragments. The whole rock is in an advanced stage of alteration, the section being filled with the products of decomposition, such as epidote, chlorite, kaolin and hydrous iron oxides. The calcite occurs in great abundance, and the hand specimen effervesces very freely when treated with cold dilute hydrochloric acid.

The rock owes its red coloration to the abundance of iron oxides distributed through it.

The majority of the plagioclase fragments, though greatly decomposed, still show the characteristic twinning.

Although the included rock fragments show tolerably fresh, lath-shaped crystals of plagioclase, their matrix is so filled with rusty decomposition products that it is well-nigh impossible to determine what bisilicates, if any, are present. The iron ore is mainly ilmenite, which is accompanied by its alteration product leucoxene.

36. TUFFACEOUS ROCK.—Greenstone Creek, one mile and a half below Big Fish Lake. 14 (1890).

A very fine-grained rock, dark-gray to almost black in colour.

The texture examined is very thick, and the rock much decomposed, rendering it almost impossible to determine its true nature. My impression is that it is a badly decomposed, siliceous, clastic rock, probably a tuff connected with some of the eruptives of the neighbourhood. Irregular, badly shattered fragments of quartz, augite, and felspar, are embedded in a very fine-grained granular matrix of apparently the same materials, but the section is so filled with a confused mass of chloritic and sericitic material, together with calcite and iron oxides, that it is difficult to make out any traces of structure in it.

37. DIABASIC TUFF.—Near Cornwall's. 247 (1889).

A dark coloured, highly calcareous rock, the elastic character of which is well seen in the hand specimen. Under the microscope it presents the appearance of a loose volcanic tuff made up of fragments of an exceedingly fine-grained, amygdaloidal, porphyritic rock, cemented together by alteration products, of which the chief is calcite.

The individual fragments resemble somewhat a pumice-stone, and before the rock was consolidated and the cavities filled up, it must have been of the nature of a very loosely coherent volcanic tuff.

Cretaceous rocks.

38. DIABASE TUFF.—East side of Fraser River, about eight miles below Lillooet. 295 (1889).

A rather fine-grained, much decomposed, but distinctly clastic rock, composed of irregular grains of plagioclase, quartz, augite, ilmenite, and titanite, together with fragments of some porphyritic basic eruptive. The thin section examined is full of chlorite, epidote, secondary biotite, and hydrous iron oxides, resulting from the alteration of the constituent minerals, of which plagioclase, greatly decomposed, predominates. The augite is mainly altered to chlorite, although a few tolerably fresh grains were observed. Ilmenite is tolerably abundant and is accompanied by leucoxene. The grains of quartz are sometimes angular and sometimes rounded in outline.

Cretaceous
rocks—Cont.

Fragments of some basic eruptive containing well-developed phenocrysts of plagioclase, and bisilicates too decomposed for satisfactory identification, are scattered through the section.

It is not always possible to determine with certainty whether a tuffaceous rock has been built up of ejected volcanic material, or has been derived from the disintegration of pre-existing eruptive masses.* Dr. Dawson informs me that this rock and the two following (Nos. 39 and 40), from the field evidence, have apparently been formed in the latter way from older diabasic rocks.

39. DIABASE TUFF.—Near Fountain. 316 (1889).

In appearance this rock greatly resembles No. 38, but is slightly darker in colour, and under the microscope their structure and composition is seen to be practically identical, No. 38, as represented by the section examined, holding perhaps a somewhat larger quantity of bisilicates than No. 39.

40 DIABASE TUFF.—Road from Ashcroft to C  che Creek, two and a half miles from Ashcroft. 120 (1890).

This is a very fine-grained, compact, dark-green, somewhat calcareous rock, which the microscope shows to be distinctly clastic in origin.

Irregular angular grains and crystals of felspar, quartz, augite, and iron ore, together with fragments of some fine-grained porphyritic rock, are cemented together by a paste of finer-grained material of the same kind, filled with calcite, chlorite, epidote, and other decomposition products.

Plagioclase is the most abundant mineral present and is much altered. A few untwinned grains of felspar were also observed.

The grains of quartz are much fractured as the result of pressure.

* See E. Royer, Ueber Tuffe und Tuffogene Sedimente. Jahrb. K.K. Geo Reichsanst., XXXI., 1881, p. 57.

Cretaceous
rocks—Cont.

The augite, although in a few instances fresh and exhibiting crystal form, is usually largely changed to chlorite, with separation of secondary magnetite in little granules.

The iron ore, chiefly titaniferous, is generally accompanied by its alteration product, leucoxene.

Some fragments of a badly decomposed basic porphyritic rock were noted in the section examined, which is also traversed by several little veins of calcite.

41. See page 389b

Tertiary
rocks.

42. GABBRO.—Arthur's Seat. 53 (1890).

A medium-grained, altered, greenish rock, composed principally of plagioclase felspar, augite, quartz, diallage (now almost entirely decomposed), iron ore, epidote, chlorite, serpentine, and apatite.

The rock is greatly decomposed, and in places has a coarse ophitic structure, causing it to approach the diabases.

The plagioclase is almost completely saussuritized.

Sharply defined crystals of augite occur as phenocrysts, also some forms which were perhaps once olivine. The augites are fresh, often polysynthetically twinned, and hold numerous inclusions.

The diallage is in broad laminae, which are almost entirely altered to fibrous aggregates of pale brownish-green serpentine and chlorite, together with granules of brilliantly polarizing yellow epidote. Titanic iron ore, in some instances accompanied by leucoxene, is abundant. A little quartz is also present.

43. QUARTZLESS PORPHYRY (ORTHOPHYRE). One mile and a half north of Spence's Bridge, west side of Thompson River. 51 (1890).

A light yellowish, decomposed rock, with marked spherulitic structure, in fact nearly the whole mass of the rock is made up of spherulites averaging three-eighths of an inch in diameter. The ground-mass of the rock is a holocrystalline fine-grained mosaic of unstriated felspar and quartz, both possessing very uneven extinction.

In this groundmass are embedded broad, irregular, kaolinized, felspar individuals. Most of the felspar in the rock occurs, however, in the form of exceedingly slender microlitic crystals, radially grouped, and forming complete star-like spherulites of felspar, which are often outlined by borders of limonite or some similar hydrous oxide of iron.

Pyrite cubes largely altered to limonite, and irregular blotches of the latter mineral, are plentiful, and the whole rock is stained a yellowish-brown from this cause.

Carbonates also occur, and there are several little cracks, filled with chalcedoni: quartz, running through the section. Tertiary rocks
—Cont.

44. MICA PORPHYRITE.* Twomiles south-east of Ashcroft. 249(1889).

A light greenish, medium-grained, porphyritic rock, in which large glassy phenocrysts of plagioclase felspar, with a most beautiful zonal structure, occur, together with a dark-brown strongly pleochroic biotite and numerous grains and crystals of magnetite, embedded in a very fine-grained groundmass composed of plagioclase, little scales of biotite, and granules of iron ore, together with, apparently, a little glassy matter.

The plagioclase phenocrysts are often in the form of two polysynthetically twinned individuals united according to the Carlsbad law.

The biotite individuals bear evidence of magmatic resorption in their corroded outlines, and frequently hold inclusions of the magnetite. A little apatite is present, but no quartz was detected in the section examined.

45. MICA PORPHYRITE.—Nicola River, three miles below Spioos River. 152 (1889).

This is essentially the same rock as No. 46, but the section, under the microscope, shows the porphyritic constituents to be more abundant, and also that a considerable quantity of a dark green hornblende is present amongst them. The groundmass, too, presents a different appearance, the felspar individuals being stouter and the "flow-structure" not nearly so marked a feature of the rock. Zonal structure is beautifully exhibited in many of the plagioclase individuals.

Evidences of magmatic resorption are numerous, especially in the case of the hornblende, the individuals of which have often more than half disappeared, the remaining portion being surrounded by a rim of little granules of magnetite. The hornblende occurs in prismatic individuals, which occasionally, where resorption has not proceeded too far, show good terminations. It possesses strong pleochroism in brownish-green to yellow tints. The biotite frequently exhibits sharp hexagonal outlines. Apatite and iron ore are tolerably abundant.

46. MICA PORPHYRITE.—Three miles east, up gully, from No. 45. 153 (1889).

This, in the hand specimen, is a very fine-grained, light grayish-white, porphyritic rock, somewhat stained with hydrous oxide of iron.

* Nos. 44, 45 and 46 were described when I was unaware of their geological position. They would correspond to the andesites of Rosenbusch, as in his classification the distinction between the two is based on their age, the porphyrites are pre-Tertiary andesites. Teall uses the term mica porphyrite for altered mica andesites.

Tertiary rocks
—Cont.

Under the microscope it is seen to consist of a fine-grained, apparently holocrystalline, groundmass, composed chiefly of small, slender, lath-shaped sections of plagioclase, together with numerous fine scales of a dark brown mica, hematite, small granules of iron ore, and carbonates.

In this groundmass, crystals of glassy plagioclase and a dark brown mica are porphyritically developed. The rock possesses a well-marked "flow-structure," the little plagioclases having a general parallel arrangement, and bending around the larger felspar crystals like logs floating in a stream. The porphyritic felspars have good crystal outlines, are mostly tabular in habit, and exhibit both binary and polysynthetic twinning. Zonal structure, though observed, is not frequent. They contain numerous microlites, and cavities filled with fluid containing bubbles, and often exhibit alteration to kaolin and calcite. The mica, probably biotite, occurs in deep brown coloured individuals with marked absorption, and occasionally possess sharp hexagonal outlines. In sections at right angles to the base, a bending of the laminae is often seen, and the individuals sometimes show corrosion on the edges, and are filled with minute inclusions, principally granules of iron ore.

Occasional sharply defined hexagonal forms of an opaque black substance resembling iron ore were observed in this section. These have been seen and described, in the case of porphyrites from various foreign localities, as being due to the magmatic resorption of the original biotite, which has been entirely replaced by magnetite.*

47. DIABASE PORPHYRITE.—Arthur's Seat. 184 (1889).

A light green, fine-grained, porphyritic rock, in which the microscope reveals a diabasic crystalline groundmass, made up of lath-shaped sections of plagioclase and irregular grains of augite. Through this groundmass are scattered numerous phenocrysts of augite and plagioclase. Irregular granules of iron ore are sprinkled through the section, which also contains much epidote, and chloritic material exhibiting spherulitic structure with the usual revolving black crosses when viewed between crossed nichols.

The felspar phenocrysts are much altered, and in many cases show no twinning striation. Occasionally several irregular shaped individuals are bunched together, forming "eyes."

The augite is remarkably fresh, usually exhibits good crystal outlines, and occurs sometimes in isolated individuals, sometimes in polysomatic groups resembling those described by Lawson in dykes from

*Cf. Rosenbusch, *Massige Gesteine*, 2nd edition, 1887, p. 452.

Rainy Lake, Ontario.* In colour it varies from pale-yellow to almost colourless, is frequently polysynthetically twinned, and possesses little or no pleochroism. Tertiary rocks
—Cont.

48. DIABASE PORPHYRITE?—Overlying the massive rocks of Battle Bluff, near Tranquille. 204 (1888).

In the hand specimen this is a greenish-gray, fine-grained rock, much decomposed, and finely pitted on weathered surfaces, owing to the removal of the porphyritic constituents.

Under the microscope the groundmass is seen to be exceedingly decomposed, with an apparently diabasic-granular structure, and composed of plagioclase and augite, with some quartz.

That the rock has been squeezed, is seen in the breaking and uneven extinction of the feldspars. The phenocrysts consist of plagioclase and augite. The whole section is filled with epidote, sometimes radially arranged, chlorite, and irregular granules of iron ore.

49. AUGITE PORPHYRITE?—Skoon-ko' Creek, below Arthur's Seat. 185 (1889).

A light greenish, fine-grained, porphyritic rock, consisting chiefly of phenocrysts of plagioclase and augite in a fine-grained groundmass composed of slender lath-shaped sections of plagioclase, some quartz, and grains of augite and iron ore.

The porphyritic augite occurs in well-formed, light green, isolated individuals, generally of short prismatic habit, but also in polysomatic groups. Sometimes these crystals have a central portion consisting of brown hornblende with characteristic cleavages, and a few isolated individuals of this latter mineral also occur. Alteration to chlorite, epidote, and carbonates, is common.

The phenocrysts of plagioclase are much altered, with formation of epidote, hydromicas, &c. A little apatite was observed. Epidote is exceedingly abundant in the rock, as may be readily seen by an examination of the hand specimen.

The uneven extinction of the constituent minerals of this rock is one of its most marked features, indicating that it has been subjected to considerable pressure.

50. AUGITE PORPHYRITE?—Skoon-ko' Creek, three miles east of Bo'tanie Lake. 207 (1889).

This rock is rather fine-grained in texture and has an amygdaloidal structure, the amygdules showing, under the microscope, a filling of

*Annual Report, Geol. Surv. Can., vol. III (N.S.), part I, 1887-88, p. 161 f.

Tertiary rocks
—Cont.

chlorite which polarizes in the usual characteristic indigo tints and is arranged in rosettes, this structure somewhat concealing the weak double refraction of the mineral. Occasionally there is an outer rim of secondary quartz in these amygdulæ. In ordinary light the sections of the amygdulæ appear filled with a light green chlorite, and sometimes have an outer rim of colourless, transparent quartz.

Slender lath-shaped sections of plagioclase occur in the groundmass, arranged in such a manner as to give a "flow-structure" to the rock.

Phenocrysts of augite, now largely replaced by chlorite polarizing in deep blue tints, hydrous oxides of iron, and carbonates, are present. Crystals of iron ore are abundant. The whole rock is much decomposed and highly calcareous, the thin section showing calcite to be abundant, and the hand specimen effervescing freely with dilute hydrochloric acid.

51. AUGITE PORPHYRITE.—Arthur's Seat. 53A (1890).

A dark grayish-green, compact, porphyritic rock, whose structure, under the microscope, approaches more closely to the augite porphyrites proper, than to the diabase porphyrite division of the general augite porphyrite group.

The groundmass does not possess the typical ophitic or diabasic structure seen in other similar rocks described in this report, but is fine-grained and apparently hypocrystalline, although the actual presence of glassy matter could not be satisfactorily proved, owing to the numerous alteration products and particles of iron ore present, and the thickness of the section examined.*

The porphyritic crystals of plagioclase are, as a rule, quite fresh and well twinned, the general form of the sections being lath-shaped. They are comparatively isolated in the groundmass, and often, by their parallel arrangement, give to the rock a rude "flow-structure."

The augite phenocrysts are large, and usually quite fresh, although many examples of more or less complete alteration to chloritic and serpentinous material, with separation of secondary magnetite, were observed. In colour, they are, when fresh, light yellowish-green to almost colourless. Polysomatic structure was frequently seen; polysynthetic twinning and zonal structure are also of common occurrence. They show uneven extinction, and hold numerous inclusions of apatite, magnetite, and fluid lacunæ.

Particles of magnetite are sprinkled throughout the groundmass.

* The rocks named augite porphyrites are for the most part greatly decomposed, and were described without reference to their geological position. They differ from the fresh glassy rocks of the Upper Volcanic Series, and I prefer in the meantime, to retain this term for them. Rosenbusch confines the name to pre-Tertiary rocks.

Some quartz occurs in the section, which, as the whole rock is greatly altered, is probably secondary in its origin. Tertiary rocks
—Cont.

52. AUGITE PORPHYRITE. Murray Mountain (summit). 224 (1889).

A rather fine-grained, dark yellowish-green, porphyritic rock. In thin sections it appears to be tolerably fresh, consisting of large phenocrysts of plagioclase and augite in a fine-grained groundmass which is apparently composed of the same materials, together with numerous granules of iron ore and a little glassy base.

Some crystals of what appears to be an orthorhombic pyroxene, now largely altered to serpentine, also occur in elongated narrow forms, as well as in smaller, stouter ones. It possesses marked pleochroism.

The plagioclase phenocrysts are tolerably fresh, full of inclusions, well striated, and possess good zonal structure. A determination of the angle of extinction in one instance showed the crystal to be labradorite. Penetration twins are common.

The augite phenocrysts have well-defined crystal form, are quite fresh, often twinned, and occur frequently in groups. Their colour is a pale yellowish-green; they show brilliant polarization colours and hold numerous inclusions. A little apatite was observed in the rock.

53. AUGITE PORPHYRITE?—Cairn Mountain. 231 (1889).

A rather fine-grained, brownish-green, rusty weathering, porphyritic rock, the hand specimen of which somewhat resembles No. 52. Plagioclase phenocrysts are abundant and tolerably fresh, but the bisilicates have been almost entirely decomposed. The quantity of iron oxides separated out in the decomposed material in the section gives one the impression that the principal bisilicate present was augite, and the rock might therefore be classed with the augite porphyrites.

54. AUGITE PORPHYRITE.—Za-kwaski Mountain. 160 (1889)

A fine-grained, brownish-gray, rusty weathering rock, with very small porphyritic crystals of plagioclase and augite.

Under the microscope the augite individuals in many instances show polysynthetic twinning according to $\alpha P\infty$. Most of the sections are parallel to the principal axis; a few at right angles to it. Some of the crystals have an outer shell which does not extinguish with the inner portion of the crystal, this zonal structure being sometimes very marked. Flow-structure is beautifully developed in the thin section examined.

Iron ore, probably magnetite, is very abundant in small grains, and a brown decomposition product is spread throughout the mass of the

Tertiary rocks
—Cont.

rock, giving a brownish tinge to the hand specimen on a freshly fractured surface.

Numerous "nests" of granular augite, epidote, magnetite, etc., occur, some of which, by their form, seem to indicate a replacement of some porphyritic bisilicate constituent.

The plagioclase phenocrysts are not nearly so abundant as those of augite. A very little quartz is present.

55. AUGITE PORPHYRITE.—Nicola River, south side, two miles above Skuh'un Creek. 168 (1889).

A fine-grained groundmass, apparently largely made up of slender little plagioclase crystals, with abundant brownish oxides of iron and chloritic material. Throughout this groundmass are scattered numerous porphyritic crystals and grains of feldspar, augite, and iron ore.

The feldspar is chiefly plagioclase, but some untwinned grains occur which may possibly be orthoclase, in which case the rock would approach the syenite porphyries in composition. Some of the feldspar individuals exhibit only binary twinning and all show good crystal form. The striated feldspar frequently exhibits an alteration to calcite.

The augite is light green to almost colourless, very faintly pleochroic, polarizes in brilliant tints, and often exhibits more or less complete alteration to a light green chloritic material.

56. AUGITE PORPHYRITE?—Three miles up Pimainus Creek. 183 (1889).

A very dark green, compact, fine-grained, porphyritic rock; the phenocrysts of feldspar being of a yellowish-white colour and showing up in marked contrast with the dark groundmass of the rock. The thin section shows this rock to be exceedingly decomposed and sheared, many of the shearing planes being marked by a deposition of feldspathic and quartzose material.

The groundmass consists of a confused aggregate of decomposition products, chiefly chlorite, carbonates, iron oxides, and pyrite.

The feldspar phenocrysts, though in an advanced stage of alteration to saussurite, calcite, etc., still show the characteristic twinning of plagioclase in many instances.

Numerous skeleton forms, some of them octagonal in outline and now filled with chlorite, secondary quartz, and other materials, probably represent the augite originally present in the rock. Pyrite is very abundant in the section, and numerous small prisms of apatite were also observed.

What little structure can still be made out leads me to refer the Tertiary rocks
rock, somewhat doubtfully, to the augite porphyrites. —Cont.

57. AUGITE PORPHYRITE.—Copper Creek Valley, east side, $\frac{1}{2}$ mile
back from Kamloops Lake. 199 (1888).

A greenish, much decomposed, highly calcareous, medium-grained,
porphyritic rock, the matrix of which is of a darker shade of green
than the porphyritic crystals.

In a thin section, under the microscope, the rock is seen to have suf-
fered extreme alteration to saussuritic, chloritic, and other decomposi-
tion products. It is full of pyrite, and stained throughout with
hydrous oxides of iron. Its alteration, however, has but little affected
the sharpness of outline of its porphyritic constituents, which, although
their original substance has now almost entirely disappeared, were
clearly plagioclase and augite. Iron ore was also abundant.

Small lath-shaped sections of plagioclase can still be seen in the
matrix, but whether glassy matter is present or not could not be satis-
factorily determined.

The rock can, without doubt, be referred to the group of augite
porphyrites, but it is hardly possible to refer it with certainty to its
exact place in that group, owing to its extreme alteration.

58. PORPHYRITE?—Hill near Murray Mountain. 218 (1889).

The rock, in the hand specimen, is much decomposed, of a light-gray
colour, mottled with whitish crystals of altered felspar. It is fine-
grained and porous in texture. On examination it proved to be so
completely decomposed that a determination of its true character would
be a matter of much difficulty, unless fresh material could be obtained.

Porphyritic crystals of plagioclase, almost entirely replaced by saus-
suritic material, and carbonates, occur in a groundmass equally decom-
posed, and apparently made up of slender little plagioclase laths with
epidote, chlorite, iron ore, and patches of crystalline carbonates.

Portions of the rock show an indistinct "flow-structure." The
original bisilicates have now entirely disappeared, their places being
taken by the chlorite, epidote and other products of decomposition
already mentioned.

59. PORPHYRITE.—Mi-mēm'oo, Nicoamen Plateau. 164 (1889).

A light greenish-gray, fine-grained, porphyritic rock, exceedingly
decomposed. Porphyritic crystals of plagioclase with well-marked zonal
structure, twinned according to both albite and pericline laws, and
showing alteration to calcite, are plentifully distributed through an
apparently holocrystalline groundmass consisting chiefly of plagioclase.

Tertiary rocks
—Cont.

In addition to the porphyritic plagioclases, many elongated forms occur which represent the original bisilicates of the rock. They are now chiefly filled with magnetite and chlorite, and, from their general appearance, were probably hornblende, although biotite may also have originally been present. They bear every evidence of having been subjected to magmatic resorption. Iron ore is quite plentiful in the section.

60. PORPHYRITE.—North side of Nicola River, four miles and three-quarters above Skuh'-un Creek. 171 (1889).

A fine-grained, greenish and deep red, compact rock. Alteration is seen, by an examination of the section, to have proceeded to such an extent as to almost entirely mask the original structure of the rock.

A few scattered porphyritic crystals of felspar, apparently plagioclase, occur in the fine-grained groundmass, and numerous patches of reddish-brown to black decomposition products, some of which have cores of bright light-green serpentinous material, probably represent the original bisilicates of the rock. The serpentine exhibits a fibrous spherulitic structure with aggregate polarization.

61. PORPHYRITE.—Nicola River, four miles above Skuh'-un Creek south side. 170 (1889).

A fine-grained, dark brownish rock, with numerous small, yellowish, white, porphyritic felspar crystals.

It is exceedingly decomposed, and consists of a very fine-grained groundmass, full of carbonates, chlorite, and other decomposition products, through which are distributed numerous porphyritic individuals of felspar, most of which, when not too much altered, show the polysynthetic twinning of plagioclase. The majority of the individuals, however, show more or less complete alteration to a grayish saussuritic material.

In addition to the felspar, a number of forms occur, now filled almost entirely with decomposition products, which were originally either augite or hornblende. Magnetite and brown or reddish oxides of iron are abundant.

A few of the highly altered forms above referred to, show small comparatively unaltered cores, which possess the cleavage of augite, and the rock may possibly be a much altered augite porphyrite.

62 PORPHYRITE (AUGITE PORPHYRITE?).—South side Nicola River, one mile and a half above Skuh'-un Creek. 176 (1889).

A much altered, light greenish, medium-grained, porphyritic rock.

Numerous phenocrysts of plagioclase and augite, both much decomposed, are embedded in a very fine-grained diabasic groundmass composed of sections of plagioclase, grains of augite, and granules of magnetite. The augite shows very uneven extinction. Tertiary rocks
—Cont.

The whole section is so filled with the products of decomposition that it is difficult to say whether glassy matter is present or not.

63. OLIVINE BASALT.—East end of Porcupine Ridge. 234 (1890).

A dark-gray, almost black, fine-grained, porphyritic rock, in which plagioclase, olivine, and biotite are porphyritically developed in a fine-grained groundmass of the same materials, thickly sprinkled with granules of iron ore, and containing some augite, together with a certain amount of glassy matter.

The plagioclase phenocrysts are clear and glassy, polysynthetically twinned, usually in long lath-shaped sections, but occasionally in stouter forms. They frequently show corroded outlines, and hold inclusions of the general groundmass of the rock. Plagioclase is also abundant in fine microlitic crystals in the groundmass.

The olivine is mostly in irregular individuals, rarely showing crystal outlines, and exhibits its characteristic alteration to a brownish serpentine, although many of the grains are remarkably fresh, and polarize brilliantly.

The biotite is in irregular scales, which are strongly pleochroic, from deep reddish-brown to pale yellow. The augite is not very abundant, and occurs as small, irregular, pale yellowish or greenish grains.

64. HORNBLENDE ANDESITE.—Porcupine Ridge, slope north of Tranquille Lake. 236 (1890).

A dark greenish-gray laminated rock, with a vitreous lustre, holding large phenocrysts of plagioclase.

The groundmass is composed of long, slender plagioclases, with a marked parallel arrangement, so thickly crowded together that but little interstitial glassy matter can be seen. In fact, the structure is almost entirely holocrystalline, but the parallel arrangement of the plagioclases, and the manner in which they bend around the porphyritic constituents, give a most typical "flow-structure" to the rock.

Distributed through this groundmass are numerous phenocrysts of plagioclase, hornblende, and augite, with magnetite, and a little apatite. Olivine and titanite occur as accessory constituents.

The plagioclase phenocrysts are mostly broadly tabular in habit, and frequently over $\frac{1}{2}$ inch long. They frequently form complicated groups of interpenetrating crystals, which sometimes form Carlsbad twins, in

Tertiary rocks
—Cont.

addition to the ordinary polysynthetic twinning. They are much altered, and hold numerous inclusions of hornblende, augite, magnetite, etc. It is possible that a few clear non-striated Carlsbad twins observed, may be sanidine. Evidences of pressure are seen in the uneven extinction and breaking of feldspars, hornblende, and augite.

The hornblende forms sometimes idiomorphic, sometimes irregular, strongly pleochroic individuals of a green colour, containing many inclusions, and frequently showing alteration to chlorite.

Augite of pale greenish or yellowish tints, sometimes with crystal outlines, more often without, is not so common as the hornblende. A few individuals of what may be an orthorhombic pyroxene, much altered, were also observed. Olivine occurs in irregular grains with characteristic double refraction and alteration to serpentine.

The magnetite frequently forms large individuals with good crystal outlines, around some of which the little feldspar laths of the groundmass bend in a most remarkable manner.

A few small crystals of titanite and apatite were observed.

65. PICRITE PORPHYRITE.—Barnes Creek Valley, north side, four miles east of Barnes Lake. 47 (1889).

A very dark green, fine-grained, compact, porphyritic rock.

Phenocrysts of olivine, and a few of augite, occur in a groundmass made up of plagioclase, augite, and glassy material.

A section of the rock was etched with hydrochloric acid and stained with fuchsin, and it was found that at least nine-tenths of the phenocrysts are olivine. A very few of augite also occur which greatly resemble the olivines.

The rock is exceedingly basic in composition and, consequently, there are no plagioclase phenocrysts, all of that mineral being in the groundmass.

66. PICRITE PORPHYRITE.—Near Watching Creek, north of Pass Lake. 245 (1890).

A dark greenish-gray rock, thickly mottled with dark brown spots representing some altered porphyritic constituent. On examining thin sections of the rock it proves to be in a very advanced stage of decomposition. Numerous skeleton forms, sometimes possessing rude crystal outlines, but often of very irregular shape and surrounded by dark rims of iron ore, are scattered thickly through the groundmass. They apparently represent phenocrysts of olivine originally present, but now replaced by serpentine, and in some instances by a colourless substance

with weak double-refraction, which appears to correspond in character with pseudophite.* Occasionally the filling consists of an isotropic substance which is probably glass. These forms are numerous, of large size, up to one-eighth inch or more, and are much fractured, the broken pieces being sometimes quite widely separated. Tertiary rocks
—Cont.

The groundmass is a confused aggregate of glassy matter, holding numerous granules and little crystals of augite, a little quartz and felspar, and iron ore in small granules. The glass is full of trichites, globulites, and other inclusions. A few forms, which may have been plagioclase, were observed, and it is probable that a little basic plagioclase was originally present, from which the pseudophitic alteration product might be derived. Clear, rounded areas, with spherulitic structure, containing chlorite, etc., which are probably partly devitrified glass, occur in the groundmass.

This rock, in spite of its poor state of preservation, is a most interesting one and should well repay further study.

67. AUGITE PICRITE PORPHYRITE.—West side of Copper Creek Valley, one mile and a half back from Kamloops Lake. 197 (1888).

A dark-green, medium-grained rock; pitted on weathered surfaces, and showing clearly the reddish, weathered-out, olivine.

An examination of the section shows that the porphyritic constituents make up fully two-thirds of the mass of the rock.

Olivine, augite, iron ore, serpentine, chlorite, epidote, and leucoxene, are the principal minerals present in the section. It is so filled with serpentinous and chloritic material, derived from the alteration of the olivine, as to make it very difficult to determine whether glassy matter exists or not; but it is probably present in the rock.

The olivine is the most abundant constituent, and occurs in large rounded phenocrysts which show in a most beautiful and remarkable manner the usual alteration to serpentine. The centres of the crystals are in most cases composed of quite fresh, colourless, olivine, possessing the usual high index of refraction, brilliant polarization colours, and other characters pertaining to that mineral.

Granules of iron ore, separated out during the process of alteration, are plentifully sprinkled throughout the crystals.

The augite occurs in well-defined yellowish crystals, occasionally twinned, with characteristic cleavage and well-marked zonal structure. They are, as a rule, much fresher than the olivines, and often occur in groups of sharp crystals.

*Cf. Kenngott, Ber. Ak. Wien, 16, 1885.

Tertiary rocks
—Cont.

Iron ore, probably mostly magnetite, although ilmenite also occurs, is very abundant in irregular grains and crystals.

The groundmass of the rock consists of a confused mass of serpentinous and chloritic material, with numerous little granules and minute crystals of augite and epidote, often collected in the form of rims around the olivine and augite phenocrysts. Glassy matter is apparently present, but, as stated above, it is difficult to identify it with certainty.

68. MICA TRACHYTE.—Savona Mountain. 147 (1890).

A pale grayish, compact, fine-grained, cellular rock; in which occur numerous minute porphyritic crystals of a glassy feldspar and a dark-coloured mica. It possesses a well marked "flow-structure." In the thin section the rock is seen to consist of a fine-grained, hypocristalline groundmass, through which are distributed numerous porphyritic crystals of sanidine, plagioclase, biotite, and acmite or aegirine. Apatite is also present.

The rock is therefore to be regarded as an intermediate form between the mica trachytes and the andesites, but is more closely related to the former.

The sanidine is in quite fresh, tabular, glassy, well formed, much cracked, idiomorphic crystals, inclosing microlites, some of which at least may be referred to augite. The sanidines possess good cleavage as a rule, and occasionally hold, in addition to the microlites, larger inclusions of the biotite, augite, and other constituents of the rock. On the whole, however, the crystals are tolerably free from foreign matter. The sections are sometimes broad and tabular, sometimes narrow and columnar. Those parallel to $\infty P \infty$, bounded by oP , ∞P , $\infty \bar{P} \infty$ are common. In one example the angle $oP \wedge \infty \bar{P} \infty$ was measured, and gave 105° . Rectangular sections at right angles to oP , $\infty \bar{P} \infty$, also occur. The outlines are occasionally rounded or irregular owing to magmatic resorption, and the crystals frequently show little bays running into them, filled with the material of the groundmass. Sometimes several individuals of irregular shape are clustered together, forming the so-called "sanidine eyes." The crystals are often bent and broken, and twinning according to the Carlsbad law, with very irregular boundaries between the two halves of the crystal, is common.

Zonal structure is beautifully developed in some cases, the extinction varying in the different layers of the crystal.

A few feldspar crystals possessing a fine microcline-like structure and undulatory extinction were observed, which may possibly be anorthoclase.

69. DACITE.—Twaal Creek, five miles and a half above its mouth. Tertiary rocks
41 (1890). —Cont.

This is a coarse-grained, light yellowish-gray rock, with numerous large porphyritic crystals of quartz and plagioclase distributed throughout.

It is remarkably free from coloured bisilicates; a few little patches of chlorite and epidote, stained with iron ore, probably representing those originally present.

Large, much fractured, phenocrysts of quartz and plagioclase occur in a fine-grained granular groundmass, composed of quartz and feldspar, with numerous little patches of calcite.

A little unstriated glassy feldspar is present, which may be sanidine.

Pyrite crystals are thickly scattered through the section, and apatite, in rather large, well-developed crystals, is also plentiful.

The plagioclase phenocrysts are tabular in form and have the *microcline* habit, that is, are glassy and colourless, resembling sanidine. They are much altered to calcite, epidote, and a greenish pseudophitic substance, similar to that which has been noted by Rosenbusch as a decomposition product of plagioclase in andesites from Kapnik and Stenzelberg in the Siebengebirge.* The average of six determinations of the extinction angle on M gave $22^{\circ} 30'$, which brings it in the labradoritic series of the plagioclase feldspars.

The feldspar of the groundmass is mainly allotriomorphic in habit, and, like the phenocrysts, is much decomposed.

The quartz phenocrysts are rounded in outline, and occasionally measure as much as half an inch in length. A close examination of the specimen reveals the fact that many of them are really doubly terminated prisms, whose edges and angles have been greatly rounded owing to magmatic resorption. They are much cracked, broken, and displaced, and are full of inclusions, such as minute colourless microclites and inclosures of the groundmass, also confused aggregates of chloritic and epidotic material, with some pyrite. Little bays run into the quartz, filled with the groundmass material.

The quartz of the groundmass has the same appearance as that usually seen in the microgranitic quartz porphyries.

70. DACITE, PASSING INTO A LIPARITE.—Upper Tranquille River.
353 (1889).

A very light pinkish-gray, fine-grained, compact, fresh looking, porphyritic rock, composed chiefly of plagioclase, an unstriated feldspar

* Massige Gesteine, 2nd Ed., Stuttgart, 1887, p. 656.

Tertiary rocks (sanidine ?), quartz, and biotite individuals, porphyritically developed
—*Cont.* in a microcrystalline groundmass.

The occurrence of a considerable quantity of unstriated felspar along with the plagioclase shows that the rock is to be regarded as a transition form between the dacites and liparites.

The quartz occurs in much cracked, rounded individuals, frequently inclosing portions of the groundmass.

Both the plagioclase and sanidine are fresh and glassy, the former well-striated, and the latter frequently occurring in large binary twins. Their outlines are much rounded, as in the case of the quartz.

The biotite, of a deep brown colour, occurs in well-formed six-sided crystals and irregular plates, which exhibit strong pleochroism and polarize in brilliant tints. Inclusions of iron ore and apatite are frequent. Little microlites of augite occur in the groundmass of the rock, through which granules of iron ore are also plentifully scattered.

71. MICA ANDESITE.—Trachyte Hills. 260 (1889).

A chalky, fine-grained, light cream-coloured, porphyritic, rusty weathering rock, which, examined under the microscope, exhibits porphyritic crystals of plagioclase and biotite, developed in a fine-grained groundmass composed chiefly of plagioclase, with a little iron ore.

The plagioclase phenocrysts are comparatively few in number, have a glassy and colourless habit, and well developed fine zonal structure. In form they are mostly tabular, the sections being rectangular or short oblong, occasionally prismatic. Binary twinning according to the Carlsbad law is common. The twinning lamellæ are not numerous in the individuals, and in one instance apparently entirely absent. In such a case it is hardly possible, without a chemical test, to assert that the individual is a plagioclase and not sanidine. A determination of the angles of extinction seems to show that most of the felspar is to be referred to the oligoclase and albite divisions. The crystals often have an uneven extinction, are cracked, and hold numerous inclusions of glassy material, prisms of apatite, granules of iron ore, and little scales of biotite. Evidences of corrosion are numerous, the sections having the angles much rounded, and numerous little bays, filled with the materials of the groundmass, running into them from all sides. A pseudophitic alteration product is developed in some instances along the cracks which traverse the crystals.

The felspar of the groundmass consists of small lath-shaped sections of plagioclase of greatly varying dimensions, mostly in the form of binary twins, though occasionally in simple individuals. Multiple

striation is very infrequent. In addition to these lath-shaped sections of felspar, other rude rectangular sections occur, some striated, but the majority not. A little sanidine might be present amongst the unstriated individuals, and, without a separation of the felspars, its determination would be a matter of extreme difficulty.

Tertiary rocks
—Cont.

The mica, which occurs in porphyritic individuals sparsely distributed through the rock, is quite fresh, of a deep brown colour, strongly pleochroic from light straw-yellow to deep brown, holds numerous inclusions of iron ore, and occasionally exhibits evidence of magmatic resorption. Little scales of this mineral are also scattered through the mass of the rock.

Slender little prisms of zircon, well terminated, are not infrequent in the section; also apatite crystals, and iron ore. The whole section is stained with yellowish-brown decomposition products.

As regards the groundmass of this rock, its felspathic constituents have already been described, but in addition to these there appears to be a certain amount of glassy interstitial matter, and the small plagioclase crystals are arranged in such a manner as to give a "flow-structure" to the rock.

Owing to the fact that the rock, as seen in the hand specimen, bears a striking resemblance to a typical trachyte, and also that the majority of the felspar individuals exhibit binary twinning only, it was thought advisable to make a separation of the felspars in order to be certain that plagioclase, and not orthoclase, is the predominating constituent.

The rock was finely powdered in an iron mortar, and the powder passed through, first, a sieve having 43 meshes to the square inch, and, finally, through one of 160 meshes to the square inch. The powder, after having a powerful magnet passed through it in order to remove any particles of iron which might have become detached from the mortar, was carefully washed and placed in a Harada apparatus filled with Thoulet's solution of specific gravity 2.670, as determined by a float of anorthite. It was found that all the powder, with the exception of a very little dark-coloured material, which was mostly mica, floated at this specific gravity. It also floated readily at 2.62. The solution was further diluted until a float of perthite (sp. gr. 2.592) just rose. At this specific gravity all the constituents sank very slowly to the bottom. The exact density of the fluid was then determined, and found to be 2.598; so that the powder must have a specific gravity of slightly over 2.60. This is the specific gravity of a felspar having the composition of albite, or of the heaviest anorthoclase.*

* See Rosenbusch, Mik. Phys. d. pet. wicht. Min., 2nd Ed., 1885, pp. 542 and 550.

Tertiary rocks
—Cont.

It has frequently been observed that in the andesites the feldspar of the groundmass are more acid than those which occur porphyritically developed. Fouqué has shown that in a pyroxene andesite from San-torin the former are albite and the latter labradorite.

72. HORNBLÉNDE ANDESITE.—North side Maiden Creek. 327 (1889).

A light brownish-gray, rusty weathering rock; consisting of a fine-grained matrix in which are embedded rather large prismatic crystals of hornblende.

Cavities filled with carbonates are numerous in the specimen, and on the outer surfaces of the rock the removal of the carbonates by weathering gives it a cavernous appearance.

Phenocrysts of hornblende and plagioclase occur in a microcrystalline groundmass composed of the same materials, in which, if any glass be present, it must exist in extremely small proportions as minute films between the grains.

The hornblende phenocrysts are brownish-green in colour, and possess rather strong pleochroism, the axis of least elasticity bisecting the acute angle. The maximum extinction angle observed was about 25°. Inclusions of the other minerals present in the section are numerous, and alteration to chlorite was observed. Twinning according to $\infty P\infty$ (100) is common. One individual is cut in a direction at right angles to the principal axis by a crystal of plagioclase, so that the section resembles a cross, the shorter cross-piece being formed by the plagioclase.

73. BASALT.—Hills between Loon Lake and Hi-hium Lake. 23 (1889).

A dark-gray, compact, fine-grained rock, which is quite fresh, and consists essentially of minute lath-shaped crystals of plagioclase, small grains and crystals of augite, and numerous granules of iron ore, embedded in a very fine-grained microfelsitic and glassy groundmass.

Patches and streaks of the groundmass, almost entirely free from plagioclase and augite individuals, occur throughout the section.

The plagioclases vary considerably in size, the smallest being mere microlites.

The augite individuals are usually very small, but, when examined with a high-power objective, are frequently seen to have good crystal forms, sometimes polysynthetically twinned.

A very few individuals of plagioclase and augite of a comparatively large size are present, and around these the smaller plagioclases bend in a manner which gives a typical "flow-structure" to the rock.

The section is somewhat stained with hydrous iron oxides.

Tertiary rocks
—Cont.

The rock is one which, according to Rosenbusch's system of classification, would be referred to the basalts, although, disregarding age, it is often well-nigh impossible to draw the line between the augite porphyrites and the basalts. Taking into consideration the freshness and glassy character of the rock, together with its Tertiary age, the writer prefers to refer it to the basalts.

74. BASALT.—Arrowstone Hills, 2 miles south of Scottie Creek. 20 (1889).

An exceedingly fine-grained, compact, light-gray rock, having a strong argillaceous odour.

Owing to the extreme fineness of grain, a satisfactory microscopic examination of the section is a matter of some difficulty. It appears to consist chiefly of minute lath-shaped crystals of plagioclase, together with little irregular grains, and occasionally eight-sided sections, of a pale yellowish-green bisilicate (usually considerably altered) having a highly inclined extinction angle, which is undoubtedly augite.

The plagioclases have a general parallel arrangement and bend around the larger augites. Glassy matter is apparently present in the groundmass, lying between the plagioclases, but this could not be definitely proved in the section examined.

75. OLIVINE BASALT.—Plateau, near Middle Branch of Tranquille River, north of Kamloops Lake. 355 (1889).

This is a very dark-coloured, somewhat porous, compact, fine-grained, porphyritic rock, with a decidedly resinous lustre, and exhibiting distinct flow-structure in the hand specimen.

A microscopic examination shows it to be a most typical and quite fresh basalt.

Plagioclase, hornblende, augite, olivine, and iron ore, occur porphyritically developed in a fine-grained groundmass made up of brownish glassy matter with embedded minute crystals and granules of plagioclase and augite; the whole possessing a well-marked flow-structure.

The porphyritic plagioclases often include portions of the glassy groundmass.

The hornblendes are brown in colour, and almost always have a dark rim surrounding them, composed of opaque iron ore and grains of augite. These rims are due to magmatic resorption of the hornblende.*

*Cf. Iddings's translation of Rosenbusch's *Microscopical Physiography of the Rockmaking Minerals*, 1893, p. 268.

Tertiary rocks
—Cont.

The olivine is almost entirely decomposed, and is now represented largely by rounded irregular patches of serpentinous material.

The augites are of a light yellowish colour and quite fresh.

76. OLIVINE BASALT.—Upper Tranquille River. 353 (1889).

A very dark-coloured, rather fine-grained, somewhat porphyritic, basic rock, which the microscope shows to be tolerably fresh and composed chiefly of plagioclase, augite, olivine, and iron ore.

Glassy, well-striated crystals of plagioclase occur porphyritically developed amongst the other constituents.

There is an abundance of serpentine developed all through the section as a decomposition product. It often has no definite form, as it would naturally have if derived from the alteration of augite or olivine, but occurs as little wedges in between the plagioclases; in such cases, perhaps, resulting from the decomposition of a glassy base. It probably originates from both sources, as it is also frequently seen surrounding cores of unaltered pale-green olivine and augite.

Owing to their extreme alteration, it is somewhat difficult to distinguish at first between the augite and olivine, but some elongated crystals with parallel extinction and, when fresh, brilliant polarization colours, were unhesitatingly referred to the latter mineral. Microlites of augite are exceedingly abundant, and granules and crystals of iron ore are evenly and plentifully distributed through the section.

77. OLIVINE BASALT.—Plateau west of North Thompson River, east and north of Caribou Lake. 193 (1888).

A medium-grained, rather light gray, crystalline, micro-porphyrific and amygdaloidal rock, which weathers to a rusty-brown colour. The amygdaloidal cavities are frequently lined with some zeolitic mineral.

The rock is composed chiefly of plagioclase, augite, olivine and iron ore.

The plagioclase occurs in broad porphyritically developed forms, as well as in lath-shaped sections in the groundmass of the rock, these latter forms frequently penetrating the augite. The phenocrysts are fresh, glassy, well-striated, and hold numerous inclusions of augite, iron ore, and other minerals, often arranged in lines around the periphery of the crystal. Determinations of the angle of extinction, measured on P, appear to show that the felspar is to be referred to bytownite. The crystals have very irregular boundaries, due to magmatic absorption, and the smaller plagioclases of the groundmass bend around them in the usual manner observed in those rocks which exhibit "flow-structure."

The groundmass plagioclase is frequently intergrown with the augite, Tertiary rocks often in such a way as to make it probable that they crystallized simultaneously. —Cont.

The augite is of a violet-brown colour, quite fresh, rather strongly pleochroic, and exhibits brilliant interference colours. It does not occur with regular crystal outlines, but intergrown with, lying between, and sometimes almost completely surrounding, the plagioclases.

The olivine is very abundant in irregular pale olive-green grains, which are usually quite fresh, although many examples of alteration to brown serpentine, accompanied by separation of magnetite, may be seen in the section. It possesses the usual high index of refraction, brilliant polarization colours, and other features characteristic of the mineral.

Iron ore, probably magnetite, is extremely abundant, mostly in irregular grains and rods.

The structure of the rock is apparently a holocrystalline one, and if glassy matter be present it must exist in very small quantity.

78. OLIVINE BASALT.—Skoatl Point. 194 (1888).

In the hand specimen this is a dark greenish-gray, rather fine-grained, porphyritic rock. Dr. Dawson states that it forms the "neck" of an old volcano from which basalt has flowed out, and is probably of Tertiary age.

Phenocrysts of plagioclase, olivine, and augite, are embedded in a fine-grained groundmass composed of lath-shaped sections of plagioclase and granules of augite, olivine, and magnetite, together with some glassy interstitial matter.

"Flow-structure" is sometimes well brought out by the arrangement of the small plagioclase crystals in the rock.

Olivine is very abundant and remarkably fresh, exhibiting only the first stages of alteration to serpentine. It occurs in little grains in the groundmass, as well as in porphyritically developed individuals. Its outlines are often rounded, a phenomenon which is no doubt due to magmatic resorption. It is frequently included in the felspar, thus showing that it is the older of the two, and itself holds numerous inclusions. In colour it is yellowish to almost colourless, and possesses good cleavage.

79. TUFFACEOUS ROCK.—Thompson River, opposite Drynoch. 188 (1889).

Tertiary rocks
—*Cont.*

A coarse-grained, light greenish, apparently clastic rock, consisting very largely of fragments of plagioclase feldspar, which are greatly decomposed.

The fragments representing bisilicates originally present, are now so entirely altered as to be unrecognizable. The section contains some quartz, also much calcite, chlorite, and other decomposition products. The rock is probably made up of material derived from basic eruptives.

[The following description is by Dr. F. D. Adams, of McGill University, who examined a thin section of the rock in question.]

70a. ALNÖITE-LIKE ROCK.—Road between Ashcroft and Savona, three miles east of Eight-mile Creek. 441 (1877).

A rock consisting of a very fine-grained groundmass in which are embedded large phenocrysts of biotite, augite, and olivine.

In the hand specimens the large plates of biotite are especially noticeable, giving the rock the appearance of an alnöite.

The olivine is now all decomposed to serpentine, or a mixture of serpentine and a rhombohedral carbonate; the biotite is also much altered. The augite is nearly colourless and possesses a barely perceptible pleochroism, these large augites are often surrounded by a darker border of a different variety of augite with a somewhat different extinction,—as in the alnöite from Ste. Anne de Bellevue,*—the small augites of the groundmass are identical in character with the outer zone.

The groundmass is composed largely of augite in little crystals. Associated with this are biotite and olivine, now for the most part altered to serpentine, together with a colourless mineral having a very low double refraction, little grains of iron ore, and little needles of apatite. The colourless mineral above referred to has never been observed twinned and is certainly not plagioclase. It is for the most part decomposed to calcite, this fact and its optical properties so far as they can be studied, point to nepheline or possibly mellilite. None of the distinctive characters of the latter mineral, however, could be observed, but so little of the undecomposed mineral still remains that its exact nature cannot be determined.

The rock, therefore, is one belonging to the group which includes the alnöite, monchiquites, and fourchites, but it is now so decomposed that its exact position in this group cannot be determined.

* See Adams, Am. Jour. Sci., vol. XLIII., 1892, p. 203.

Dr. Dawson states that the rock is probably a dyke of Tertiary age, but that the rocks at the locality are much broken and confused.

41. QUARTZ AUGITE DIORITE, WITH SOME BIOTITE.—Forge Mountain. Plutonic
rocks.
32 (1890).

A medium-grained granitic rock, showing in the hand specimen light grayish felspar, dark green hornblende, and magnetite.

The microscope shows it to consist essentially of quartz, plagioclase, orthoclase, hornblende, augite, and biotite, together with magnetite, apatite, chlorite, epidote, titanite and zircon.

The quartz is the ordinary granitic variety, filling in the spaces between the felspars.

Plagioclase is the predominating felspar, and occurs in broad, well striated, much altered, often nearly opaque, individuals, with a decided tendency to idiomorphic development. Some non-striated irregular shaped grains, also much altered, are probably orthoclase.

The hornblende occurs in brownish-green individuals, sometimes possessing a somewhat fibrous structure, and often interspersed with augite. Twins are not uncommon, and the mineral usually exhibits more or less alteration to chlorite, and is sprinkled with granules of magnetite and other inclusions.

Augite, besides occurring as described, associated with the hornblende, is also present in isolated individuals, generally much altered to chlorite, bright yellow epidote, and calcite, the brown colour being changed to green. Lenticular patches of calcite filled with minute needles and granules of epidote, causing the whole to polarize most brilliantly, have separated out between the folia of the hornblende.

80. QUARTZ MICA DIORITE.—Near Pukaist Creek, three miles east of Thompson River. 35 (1890).

A medium-grained, holocrystalline rock, in which the felspar, of a light greenish colour owing to alteration, is mottled with dark-coloured hornblende and biotite.

It is composed of plagioclase, orthoclase, quartz, biotite, hornblende, pyroxene, magnetite, apatite, and epidote.

The plagioclase, which predominates largely over the orthoclase, possesses uneven extinction, shows a marked tendency towards idiomorphic development, and is, together with the orthoclase, much decomposed.

Quartz is tolerably abundant, extinguishes very unevenly, and occurs in little granulated areas throughout the section.

Plutonic
rocks—Cont.

Biotite is plentiful, largely altered to chlorite and epidote; the hornblende also is much decomposed and occurs intimately associated and intergrown with the biotite and pyroxene.

The monoclinic pyroxene is quite abundant in the section, is of a pale green colour, and considerably altered to epidote and a light-green chlorite. Little granules of secondary magnetite are plentifully scattered through the altered crystals of this mineral. Frequently a core of comparatively fresh pyroxene may be seen surrounded by fibrous hornblende, which no doubt has resulted from its alteration.

The bisilicates are all much stained by brown hydrous oxides of iron.

81. QUARTZ MICA DIORITE.—Six miles up In-ki-kuh' Creek. 36 (1890).

A rather coarse-grained holocrystalline rock, consisting of a light-coloured quartz and felspar matrix, in which numerous flakes of dark-brown mica of good size, and smaller individuals of hornblende and iron ore are embedded.

The minerals composing it are plagioclase, orthoclase, quartz, biotite, hornblende, magnetite, titanite, apatite, epidote, chlorite, and zircon.

The plagioclase felspar is the more abundant, is well-striated, and considerably altered to saussuritic material. It possesses, in common with the orthoclase and quartz, a very uneven extinction, due to pressure.

The biotite shows decompositions and alteration to chlorite, and, consequently, often presents a somewhat fibrous appearance. The hornblende, also considerably altered, presents no unusual features. It is strongly pleochroic in green and yellowish-brown tints.

Titanite and magnetite are abundant, often occurring in large grains. A few short, stout, crystals of zircon were observed, sometimes embedded in the biotite.

82. CRUSHED GRANITE.—Guichon Creek, west side, one mile south of Witches Brook. 26 (1890).

This is a fine-grained, light greenish, somewhat rusty, granitic rock, possessing in the hand specimen a distinct finely-laminated structure. It is stated by Dr. Dawson to occur near the contact of a mass of granite with rocks of Triassic age.

Under the microscope it is seen to consist of a fine-grained interlocking mosaic of quartz and felspar, in which larger grains of the same materials are embedded.

Little scales and a few larger flakes of biotite, sometimes altered to chlorite, are scattered plentifully throughout the rock, and grains of magnetite are also abundant. Small quantities of apatite and titanite are also present.

Orthoclase and plagioclase both occur in a greatly decomposed condition and exhibit, together with the quartz, very uneven extinctions, having evidently been subjected to intense dynamic action. The larger grains are much cracked, and reduced to a fine mosaic of crushed material around their edges.

A rude laminated structure is given to the rock in the thin section by the parallel arrangement of the flakes of biotite. It is most probably a granite which has been subjected to great crushing action.

83. GRANITE PORPHYRY.—East side of Barnes Lake. 48 (1889).

A medium-grained, light greenish-gray, granitic rock; blotched with porphyritic, olive-green, decomposed felspar.

It is composed essentially of orthoclase, plagioclase, quartz, and very small quantities of some much altered bisilicates, together with iron ore, chlorite, epidote, apatite, sphene, and hydrous oxides of iron.

Many portions of the section examined show a distinct coarse granophytic intergrowth of the quartz and felspar. The latter occurs sometimes in large, porphyritically developed, crystals; and the whole structure of the rock suggests the first transition stage of a granite passing into a quartz porphyry.

The rock, as far as one can judge from the single section, is holocrystalline, no glass or interstitial matter being detected.

The felspars are so exceedingly altered that the irregular grains of the quartz stand out in bold relief, giving at a first glance an almost clastic appearance to the section.

Bisilicates occur in very insignificant quantities, and are mostly represented by brownish chloritic and epidotic material, associated with granules of iron ore. In a few instances the original mineral was judged to have been biotite. Iron ore, probably magnetite, is quite abundant, and several small grains of sphene were also observed.

84. PORPHYRITIC DIABASE.—Road between Ashcroft and Savona, six miles from Ashcroft. 129 (1890).

This is a medium-grained, dark-green and yellowish-brown mottled rock, in which the microscope shows a fine-grained portion, having the ophitic structure of a diabase, and holding porphyritically developed crystals of plagioclase and augite.

Plutonic
rocks—Cont.

Plutonic
rocks—Cont.

The plagioclase phenocrysts show an extreme stage of alteration to saussuritic material.

The whole rock is much decomposed, and consists chiefly of plagioclase, pyroxene, biotite, a little quartz, iron ore, apatite, and pyrite.

Both augite and diallage are present in the rock and are greatly altered to chloritic, serpentinous, and epidotic material, with deposition of granules of secondary magnetite. The augite is light-green in colour and polarizes in brilliant tints. The phenocrysts of this mineral are greatly decomposed.

Two sections of this rock were examined, one of which contains much more biotite than the other. The biotite is of a curious deep reddish-brown colour, and strongly pleochroic. It is apparently secondary in origin, and occurs intimately associated with the confused tufted and fibrous aggregates of serpentinous and chloritic material resulting from the decomposition of the bisilicates. The iron ore is chiefly ilmenite, accompanied by leucoxene. This rock, No. 96, and No. 99, resemble each other in the hand specimens and have the same general mineral composition, but the rock now under consideration is porphyritic, and exhibits a phase of structure more closely approaching that of a coarse-grained porphyritic diabase. The difference in structure would readily be produced by a difference in the rate of solidification of the magma.

85. BIOTITE HORNBLÉNDE GRANITE, or HORNBLÉNDE GRANITITE.—
Summit of Chi'pocin Mountain. 266 (1889).

In the hand specimen the rock presents the same general appearance as No. 92. It is thoroughly holocrystalline, consisting principally of orthoclase, plagioclase, quartz, biotite, and hornblende; with titanite, iron ore, apatite, zircon, chlorite, and epidote, as accessory constituents.

The felspars, as a rule, are not greatly altered, although some individuals show more or less complete saussuritization. Zonal structure is common; they also possess very uneven extinction, and are filled with various inclusions, amongst which are little blood-red transparent scales of hematite. The plagioclase felspar is quite abundant and frequently exhibits excellent examples of pressure-twinning.

The quartz is the usual granitic variety and forms a rather fine-grained mosaic between the felspars.

Biotite is abundant, quite fresh, strongly pleochroic, and often intergrown with hornblende, which presents no unusual features and is frequently altered to chlorite.

Titanite is abundant, occurring mostly in large irregular grains: Plutonic
apatite is also present in small, rather stout, crystals. Several stout rocks—Cont.
crystals of zircon, showing a zonal structure, were observed.

Chlorite, epidote, and iron ore are abundant, the latter sometimes accompanied by a substance which is apparently leucoxene, indicating that some titanitic iron is present; but a test of the powdered rock showed that magnetite is very abundant.

As regards the nomenclature of this rock and No. 92, much plagioclase is undoubtedly present, and a separation of the feldspars in each case would be necessary in order to determine whether the rocks might not perhaps be more properly termed quartz diorites. In the absence of such determinations, and from a close examination of the sections submitted to me, I prefer at present to refer them to the granites.

86. HORNBLÉNDE GRANITE.—Three-lake Valley. 386 (1877).

A medium-grained, light pinkish, decomposed granitic rock, which, judging from the hand specimen, has a "miarolitic" structure; that is, it possesses small cavities into which the corners and edges of the crystallized mineral components project.*

It consists of a holocrystalline aggregate of orthoclase, plagioclase, hornblende, apatite, and iron ore; with epidote, chlorite, kaolin, and hydrous iron oxides, as decomposition products. Little areas of granophyre are numerous in the section.

The quartz is the ordinary granitic kind and holds numerous inclusions. The feldspars, especially the plagioclase, are greatly decomposed to a dull whitish opaque substance. The bisilicates originally present are now almost entirely altered to chlorite, epidote, etc. Some comparatively unaltered fragments, which were examined carefully, proved to be hornblende. Aggregates of brilliantly polarizing epidote granules are abundant.

Both magnetite and ilmenite appear to be present, the latter frequently accompanied by leucoxene resulting from its alteration.

87. HORNBLÉNDE BIOTITE GRANITE.—Between Campbell Creek and Kamloops. 108 (1889).

A medium-grained, holocrystalline rock, exhibiting in the hand specimen a light-coloured groundmass, blotched with dark hornblende and mica, and somewhat stained with hydrous iron oxides. It approaches in composition to the quartz diorites, in that plagioclase feldspar is very abundant, equalling in quantity, if indeed it does not exceed, the orthoclase.

* Cf. Rosenbusch, Mik. Phys. der mass. Gesteine, p. 39, 1887.

Plutonic
rocks—Cont.

The minerals present are quartz, orthoclase, plagioclase, hornblende, biotite, ilmenite, titanite, apatite, zircon, and pyrite. The quartz is the ordinary granitic variety, is much cracked, and possesses very uneven extinction in common with the felspars. Both orthoclase and plagioclase are considerably decomposed; the latter is well striated and often possesses a marked zonal structure. It also exhibits a tendency to idiomorphic development, and the same crystal, in addition to the ordinary fine twinning striation, will frequently show twinning on the Carlsbad plan.

The hornblende, which is tolerably unaltered, occurs in irregular individuals, and also in well defined crystals which are strongly pleochroic in light yellowish-brown to dark green tints. The crystals are frequently twinned parallel to the orthopinacoid.

The biotite presents a fibrous frayed-out appearance and is altering to chlorite. Zircon and apatite are among its included minerals.

Titanite and iron ore are not very abundant in the section.

The rock in its general character somewhat resembles a granite from the Stikine River, described by Dr. Adams.*

88. CRUSHED GRANITE.—North side of Kamloops Lake, near Copper Creek. 161 (1890).

A rather coarse-grained, much decomposed, light grayish, granitic-looking rock, holding numerous patches of rather bright yellow altered felspar; the whole spotted with small rusty dolomite and calcite crystals and little spangles of silver-white mica, the former giving a general pinkish hue to the specimen. It effervesces freely with dilute hydrochloric acid.

A microscopical examination shows it to be made up chiefly of fragments of quartz and felspar cemented together by a fine mosaic of the same materials, affording a good illustration of Törnebohm's "mortar-structure" (Ger. *mörtelstruktur*.†)

Numerous irregular patches and small crystals of very rusty carbonates are scattered throughout the section, together with scales of pale green chlorite and a colourless hydro-mica. A few small zircon crystals were also observed. Patches of granophyre are not uncommon, sometimes surrounding felspar individuals.

Both orthoclase and plagioclase are present, generally in a much altered condition, the larger grains, together with the quartz, being cracked, bent, and granulated on their edges.

* Annual Report, Geol. Surv., Can., vol. III. (N.S.), Part I., 1887-88, p. 238 B.

† Geol. Fören. Förhandl., 1881, V, p. 233.

The quartz shows uneven extinction in a less degree than does the felspar, but is much broken. The rock is probably a granite which has been subjected to great crushing action. Plutonic rocks—Cont.

89. SYENITE (PORPHYRITIC).—Edwards Creek. 81 (1889).

A rather coarse-grained, holocrystalline, light pinkish or yellowish-gray rock, with large porphyritic felspar crystals thickly scattered through it. Its texture varies considerably in different portions of the mass. That it has been considerably squeezed is shown by the crushing and undulatory extinction of the component minerals.

The minerals composing it are orthoclase, plagioclase, microcline, biotite, some hornblende largely altered to chlorite, titanite, ilmenite, apatite, zircon, calcite, epidote, sericite, and pyrite.

Very little, if any, quartz is present. It was searched for amongst the crushed mosaic of felspar grains lying between the phenocrysts, but could not be identified with certainty. The felspars are much decomposed and often exhibit a zonal structure. Titanite is very abundant in large irregular single grains and aggregates, and is frequently associated with ilmenite. An exceedingly minute yellow metallic particle was thought to be gold, and Dr. Dawson has since informed me that an assay has been made which showed that appreciable traces of that metal exist in the rock.

90. AUGITE SYENITE. North Branch Bonaparte River, near the mouth. 336 (1889).

A rather coarse-grained holocrystalline rock, which in its structure differs somewhat from a typical syenite.

The principal mineral constituents are orthoclase, microcline, augite, biotite, apatite, magnetite, and zircon. Quartz was not detected in the section examined.

The orthoclase presents the usual characteristics of the variety commonly occurring in granites. A curious micro-perthitic intergrowth of the felspars is of very common occurrence. A felspar resembling anorthoclase is rather abundant in the section in very finely striated grains. In sections at right angles to P and M this felspar exhibits a very fine microcline-like twinning striation.*

The augite is of a clear light-green colour, occurring in irregular grains and sometimes in rude octagonal sections. It is often intimately associated with the biotite, which is of a deep brown colour and strongly pleochroic.

* Rosenbusch, Mik. Phys. d. pet. wicht. Min., 3rd Ed., 1892, pp. 679-680.

Plutonic
rocks—*Cont.*

Apatite in large stout crystals and irregular grains is very abundant. Magnetite is also plentiful, and a few zircons were observed.

The rock shows considerable saussuritization of the feldspars, and the section is stained throughout with brownish decomposition products resulting probably from the alteration of bisilicates.

91. HORNBLende GRANITE.—East side Fraser River, seven miles north from mouth of Cinquefoil Creek. 274 (1889).

This is a medium-grained, dark-green and white rock, which, examined microscopically, is seen to be composed chiefly of orthoclase, quartz, hornblende, and a little plagioclase feldspar; also titanite, epidote, chlorite, and iron ore.

Cataclastic structure is remarkably well-developed, the very uneven extinction and crushing of both quartz and feldspar being evidence of the intense dynamic action to which the rock has been subjected.

The feldspar, as usual, is not so badly shattered as the quartz, but, like it, possesses very uneven extinction. The quartz shows every gradation from slightly uneven extinction to complete shattering of the grains. The hornblende is intensely pleochroic in yellowish-brown to deep green tints, and is altering to chlorite and epidote. Much titanite and epidote are present, the former often in rude crystals as well as in irregular grains.

92. BIOTITE HORNBLende GRANITE, OR HORNBLende GRANITITE.—East side of Fraser River, four and a half miles above Cinquefoil Creek. 273 (1889).

This rock, whilst resembling No. 91 in the hand specimen, does not exhibit such marked cataclastic structure when microscopically examined. Biotite is also present, and plagioclase is much more abundant.

Its component minerals are orthoclase, plagioclase, quartz, biotite, hornblende, iron ore, chlorite, apatite, zircon, epidote, and titanite.

The feldspar is considerably altered, and frequently exhibits a beautiful zonal structure. Biotite is abundant in quite large individuals, often bleached and altered to chlorite. The hornblende, also showing alteration to chlorite, occurs intimately associated and intergrown with the biotite. Iron ore in irregular grains is very abundant, and sometimes accompanied by a grayish substance resembling leucoxene; so that the iron ore in these instances is no doubt ilmenite.

93. QUARTZ MICA PORPHYRITE.—Kl-ow-a Mountain. 76 (1890).

In the hand specimen this is a grayish-white, fine-grained, compact, felsitic-looking rock, through which are distributed numerous porphy-

ritic individuals of quartz, felspar, and a dark-coloured, almost black, mica. Plutonic
rocks—Cont.

Seen under the microscope the groundmass of the rock consists of a very fine-grained mosaic of quartz and felspar, in which the phenocrysts of quartz, felspar, and biotite, are embedded together with garnet, epidote, chlorite and apatite. Very few phenocrysts are present in the section examined, but these appear to consist chiefly of plagioclase.

An examination of quite a number of sections would be necessary to determine the question as to whether the rock should be referred to the porphyrites, in which plagioclase predominates, or to the porphyries, in which orthoclase is the prevailing felspar. Dr. Dawson states that the rock forms a dyke cutting granite of the Coast Range.

94. QUARTZ PORPHYRY, PASSING INTO QUARTZ PORPHYRITE.—North side of Seton Lake. 297 (1889).

A very light coloured, grayish-white, medium-grained, granitic-looking rock, occurring, according to Dr. Dawson, in the form of a large dyke.

Under the microscope it is seen to possess some remarkable features.

Porphyritic crystals of quartz which are sometimes sharply idiomorphic, together with idiomorphic plagioclases, are embedded in a microgranitic groundmass which is apparently chiefly composed of grains of unstriated felspar, and perhaps a little quartz, although the latter mineral was not determined with certainty.

The porphyritic plagioclases show well-developed zonal structure, and often occur in interpenetrating twins with the usual striation.

A determination of the extinction angles shows that they are intermediate in composition between oligoclase and labradorite, with the centre more basic than the outer portion.

Small quantities of biotite and hornblende, much altered to chlorite, are present.

The rock is altogether a remarkable one; the plagioclase is unusually basic to be associated with so much quartz, and there is an unusually small quantity of coloured bisilicates for a porphyrite.

Sections were submitted to Dr. F. D. Adams and Prof. A. P. Coleman, and the writer is much indebted to these gentlemen for their views regarding the rock. They agree with him in regarding it as a quartz porphyry, which, from the large amount of plagioclase present, is passing into a quartz porphyrite.

Plutonic
rocks—*Cont.*

95. AMPHIBOLITE.—Stein Mountain. 83 (1890).

A fine-grained, dark-green, somewhat schistose rock, in which the microscope reveals the fact that it has been subjected to intense dynamic action, and so sheared and crushed as to almost entirely obliterate its original structure.

Finely granulated plagioclase, the individual grains of which exhibit very uneven extinction, is mingled with confused aggregates of hornblende, chlorite, muscovite, and a dark-brown mica, these minerals also occurring in isolated scales and minute crystals scattered through the felspar.

Many forms occur almost entirely altered to chlorite or some other substance, an alteration accompanied by the separating out of magnetite in small granules, which are now thickly sprinkled through the mass. These forms, by their general appearance, suggest that the original mineral may have been pyroxene.

Zircon, apatite, and little cubes of pyrite mostly altered to limonite, were observed, and the whole section is permeated by hydrous oxides of iron, to which its brown coloration is due. The hornblende is largely in the form of slender needle-like crystals which are probably actinolite.

The constituent minerals as seen in the section have a distinct parallel arrangement, and the rock, which Dr. Dawson informs me occurs as a dyke cutting granite, is doubtless a much squeezed and altered basic eruptive.*

96. GABBRO.—North end of Coal Hill Ridge, near the road. 1 (1888)

A medium-grained, dark-green rock, mottled with whitish felspar.

It has a granitic structure, and is composed of plagioclase felspar, augite, ilmenite usually accompanied by leucoxene, chlorite, and epidote. The specimen is in an advanced stage of alteration, the felspar being changed almost entirely to a confused mass of saussuritic material.

The augite, though less altered than the felspar, is changing in many instances to pale green chloritic and serpentinous substances. Twinned grains are not infrequent. Iron ore is quite abundant.

97. GABBRO, APPROACHING DIABASE IN STRUCTURE.—Behind Battle Bluff. 202 (1888).

This is a mottled, pink and dark-green, rather coarse-grained and much decomposed rock, consisting chiefly of plagioclase, augite, a little quartz, and ilmenite, together with epidote, chlorite and apatite.

* See notes on Nos. 8 and 9, pp. 352-353 B.

The plagioclase is almost completely saussuritized, and the augite, which is much cracked, is largely altered to chlorite and epidote. Plutonic rocks—Cont.

Ilmenite, accompanied by its alteration product leucoxene, is abundant. Epidote is also plentiful and is intensely pleochroic, from deep yellow to almost colourless.

Apatite in irregular grains and crystals is of frequent occurrence.

The plagioclase individuals are broad, and the structure of the rock is intermediate between that of a gabbro and that of a diabase, some portions of the sections showing an approach to the granitic structure of the former, whilst others again have a coarse ophitic structure.

On the whole, the writer is inclined to refer the rock to the gabbros rather than to the diabases.

98. GABBRO, APPROACHING DIABASE IN STRUCTURE.—Near Edith Lake. 249 (1890).

A fine-grained, pale green, decomposed rock, consisting of plagioclase, augite, iron ore, chlorite, epidote, and apatite.

As seen in the thin section the rock is greatly altered, the plagioclase feldspar being partly converted into saussurite. A curious regular "lattice-structure" is often to be seen in the arrangement of the scales of sericite derived from the alteration of the plagioclase.

The rock does not possess a strictly typical gabbro structure, portions of it showing a very coarse ophitic structure, which tends to ally it with the diabases.

The augite is very pale green to colourless when fresh, but is generally much altered to chlorite and epidote. It exhibits a tendency to idiomorphic development. Iron ore, probably magnetite, is abundant. This specimen must be classed with No. 97 as regards its structure.

99. PORPHYRITIC DIABASE.—Cherry Bluff. A (1888).

This rock in the hand specimen is fine-grained, of a dark olive-green colour, with porphyritic crystals of plagioclase feldspar, which, in comparison with the main mass of the rock, are of large size. Augite also occurs porphyritically developed, in exceedingly decomposed crystals.

The structure of the specimen is that of a typical diabase, its ophitic character being marked, and it possesses but very little groundmass.

The plagioclase feldspar, though not extremely altered, is much cracked, full of inclusions, extinguishes very unevenly, and is stained with brown decomposition products derived from the augite. It often forms binary twins, and possesses a most beautiful zonal structure. A number of determinations of the angle of extinction, measured between

Plutonic
rocks—*Cont.*

two adjacent lamellæ, shows that it is to be referred to the labradorite group of the plagioclase series.

Both the augite filling the interstitial spaces of the felspar and that porphyritically developed, are extremely altered to a deep yellowish-brown serpentinous substance. Some of this decomposition product may possibly represent olivine originally present in the rock, but this is somewhat doubtful, and could not be proved in this particular instance. Iron ore, probably magnetite, is plentiful, sometimes possessing sharp crystal outlines. A few minute zircons were seen. Apatite and epidote are also present.

100. TUFFACEOUS ROCK.—Cherry Bluff, near west end. B (1888).

A rather fine-grained, olive-green, rusty weathering rock, which, as shown by the microscope, possesses a distinctly clastic structure and is made up of fragments of felspar (some unaltered grains occur in addition to undoubted plagioclase), augite, much epidote, chlorite, and iron ore. No quartz was observed in the section, which is stained with hydrated oxides of iron.

Only a comparatively small amount of unaltered pale green augite remains, the large quantity of epidote and chlorite observed having no doubt in great part resulted from the decomposition of that mineral, and perhaps of other bisilicates originally present in the rock.

Although thus shown to be of clastic origin, this rock is placed here because indistinguishable from the main eruptive mass of Cherry Bluff, in which it has been caught up.

APPENDIX II.

SHUSWAP NAMES OF PLACES WITHIN THE AREA OF THE KAMLOOPS MAP-SHEET.

[Extracted from a paper entitled *Notes on the Shuswap People of British Columbia*, by GEORGE M. DAWSON. Trans. Royal Soc. Can., vol. IX., (1891) sect. II.]

The alphabet employed is identical with that of the "Comparative Vocabularies of the Indian Tribes of British Columbia," and is as follows:—

Vowels.

a, as in English	fat.
ā, " "	father.
e, " "	met.
ē, " "	they.
i, " "	pin.
ī, " "	marine.
o, " "	pot.
ō, " "	go, show.
u, " "	nut, but.
y, " "	year.
ai, " "	aisle.
ei, " "	vein.
oo, " "	pool, fool.
eu, " French	peu (seldom used).
ow, " English	now.

The distinction of long and short vowels (following Gibbs) is noted as far as possible, by the division into syllables,—the consonant that follows a vowel being joined immediately to one intended to be pronounced short, while a long vowel is left open, being followed by a hyphen. When this is insufficient, or a nicer distinction is desirable, the usual long and short marks are supplied.

Explosive or clicking sounds are represented by the letters k, t, etc., in combination with an apostrophe, thus 'k 't.

An acute accent (') at the end of a syllable indicates its accentuated character, when this is very distinct. Strongly guttural syllables are printed in small capitals, thus,—law-KH.

Indian Names.	Name Adopted, or Description of Place on the Map.	Meaning Given for Indian Name.
A-kaz-ik'	A-kaz-ik' Mountain.	
As-köm'	As-köm' Mountain.	The Mountain.
Botanie.	Botanie Lake, etc.	Perpetual root-place. ?
Hai'-in-wolh.	Deadman River.	Circling or detour.
He-mäm'-aitl.	Big Fish Lake.	Big Trout. ?
Hi-äh'-kwa.	Hi-äh'-kwa Lake.	Long Lake.
Hi-hium'	Hi-hium Lake.	Trout Lake.
Hloo-léu.	Lac le Bois.	Diver Lake.
Hoom-it-ä'-lis.	Stony Creek.	
Häm-ilt-kwä-ilt.	Small lake below Big Bar Lake.	Young Fish Lake.
Hup-häp'.	Hill on west side Copper Creek.	Slaty.
Hut-tat-tal.	Old village site near Kelley Lake.	Cold Spring.
I-is.	Campbell Creek.	
In-hä-höt'.	Eighteen-mile Creek.	Dry.
In-ka-kën.	Mountain 4 miles north of Za-kwas'-ki.	
In-ki-kuh'.	In-ki-kuh' Creek.	Sometimes dry.
In-koi'-ko.	In-koi'-ko Creek.	
In-pa-ät'-kwa-ten.	Pavilion Lake.	
In-skwa-täm.	Red Creek.	Red.
In-tl-pam.	In-tl-pam Creek.	Deep.
In-toi-a'.	In Marble Mountains.	Overhung Mountain.
In-whois'-ten.	Bridge River.	
Ka-ka'-kows.	Pass Lake.	
Kil-a-paus.	Lower part of Scottie Creek.	
Kit-sa-min'.	Edward Creek.	Drift pile.
Kla-häl.	Loon Lake.	
Klim'-la-la-me.	Medicine Creek.	Medicine.
Kl-ow'-a.	Kl-ow-a Mountain and Creek.	Green.
Kluh-tows.	Bonaparte River.	Gravelly River.
Kok-lä-kä.	Shunway Lake.	
Kuk-waus'.	Kuk-waus' or Bonaparte Lake.	Spear-head Lake?
Kwil-äl'-kwila.	Green Mountain.	Green Mountain.
Kwin-tsha'-ten.	Small stream joining Nicola above Skuh'-un.	
Kwio-hau'k.	Cairn Mountain.	Open or clear.
Kwöm'-a-kun.	Skull Hill.	Skull hill.
La'-loo-wissin.	La'-loo-wissin Creek.	
Ma-mit.	Mamit Lake.	Whitefish.
Me-toots'.	At forks of Bonaparte.	Projecting point.
Na-ai-ik.	Guichon Creek, mouth.	Bearberry (<i>Arctostaphylos</i>).
Na-kwäs'-tam.	Eleven-mile Creek.	Deep.
Ne-kin-ish-tam'.	Chasm Creek.	
Ne-wil-whoos.	Ridge lake.	Ridge lake.
Ni-a-an'-tun.	Botanie valley as a whole.	
Ni-kow-men.	Nicoamen River.	
Ni-hlip'-tow'-us-tum.	Small stream next above Kelley Creek.	Going-over stream.
Nim-nim-wh'.	Mountain 4 miles north-east of Za-kwas'-ki.	
O-o-pax'.	Opax Hill.	
Pe-tloosh-kwo-hap'.	Pe-tloosh-kwo-hap' Mountain.	
Pi-mai-nus.	Pimainus Creek and Lakes.	
Pip-tautl.	Trout Lake.	Trout.
Pis-i-tsoots'-i-a.	Porcupine Ridge.	Porcupine place.
Pis-ki-ki-al.	Small lake near Ridge Lake.	Chief-hare.
Ptl-nä'-m'a.	Fly Creek.	Blue-bottle fly.
Ptl-nil-min.	Poison Hill.	Poison-weed (<i>Vernatrum</i>) place.
Ptl-tik-moos'.	Young Lake.	Sucker.
Puh-hä'-ha-nih.	Ridge running west from Cairn M'tn.	
Pu-kaist.	Pu-kaist Creek and village.	White.
Pu-kö'-kila-hoom.	Big Bar Lake.	Deep, with shallow margin.

Indian Name.	Name Adopted or Description of Place on the Map.	Meaning Given for Indian name.
Put-hil-i-hil	Three-lake valley	<i>Potentilla anserina</i> .
Shaw-ow-itlan	Mouth of Jamieson Creek	The portage.
She-kuk'-ilwh	Lower part of Sandy Creek	
Shit-shoo'-tl	Allen Creek	It dries up.
Shloot	Fraser River near Leon Creek	The eddy.
Shoopem-hat'-kwa	South Thompson	Shuswaps' river.
Sil'-whoi'-a-kun	Sil'-whoi'-a-kun	Caribou place.
Sin-po-at'-kwa	North Thompson	North river.
Si-o-kun	Trapp Lake	
Sitz-kwok'-sum	1½ mile below Leon Creek	Looking up.
Si-who'	St-who' Creek	
Skem-a-kaim'	Lower end of Seton Lake	
Ski'-hist	Ski'-hist Mountain	Face.
Ski-kloosha	Face Lake	
Skoon-kó'	Skoon-kó' Creek	
Skoo-talis	Hills between Thompson, Bonaparte and Cache Creek	
Skoo-wat'-kum	Skull Creek	Pointed or upstanding
Sko-whautl	Skoatl Point	Stony.
Skuh'-un	Skuh'-un Creek	
Skuk'-e-uke	Mountain 3 miles north-north-east of Zakwas'-ki	Thunder hill.
Skup kak-wa	Sandy Creek	Sandy.
Sku-skul-a-hat'-kwa	River Lake	
Skutl-heh'-tl	Gnawed Mountain	Eaten to the bone.
Skwil-a'-tin	Kelley Creek, lower part	Big hill.
Skwil-kwa'-kwil	Skwil-kwa'-kwil Mountain	The highest.
Spa-áist	Spaist Mountain	Burnt.
Spap-sil-kwa	Glen Hart	The lakes.
Spa-tsin	Spa-tsin Lake	Burnt lake?
Spép'-sun	Spatzum	<i>Asclepias speciosa</i> .
Spil-al-hw	Eagle Hill	Eagle.
Spilim-at'-le-la	Near mouth of Cache Creek	Brook at the flat.
Spil-má-moos	Maiden Creek	Little flat.
Spil-pál'-um	Clinton Creek	Prairie flat.
Spit'-poo-thun	Marble Cañon	Narrow valley which opens.
Spit-ti-kwous'	Pass from Hat Creek to Jack's Creek	The defile.
Sta-ai'in or Ste-in	Stein Creek	
S'tim'-what-kwa	Fraser River near Lillooet	Lillooet's river.
S'tl-pó'-mun	Upper part of Hat Creek valley	Opening out.
Swuz-uk-ain'	Botanic Mountain	
Tai-a-ka	Tai-a-ka Lake	
Ta-tlh	Small stream 1 mile north of Fourteen-mile Creek	
Ti-há-mia	Stump Lake	
Tik-i-máx'	Tranquille River	Point (river).
Til-kwo-kwé'-ki-la	Tranquille River, near mouth	Name of a root.
Til-kwa-si-shoo	One of the Red Lakes	
Titl'-whiloom	Three-mile Creek	
Thirt-li-put-ám'	Macaulay Creek	Balsam-fir ravine.
Toon-kwa	Toon-kwa Lake	Goose lake.
Tow-il-ta-kai	Fifty-mile Creek	Mountain brook.
Tshi-it'-lin-stum	Eating Lake	Eating.
Tshil-tshil'-nuts	Lakes in Highland Valley	Slightly saline.
Tshi-nut-sim	Blue Ravine	Washed out.
Tshi-poo-in	Summit of pass near Chi'-poo-in M'tn	A cache in the ground.
Tshi-wó'-us	Mountain 3 miles north of Zakwas'-ki	
Ta-o-ha-mous	Chayooch Creek	
Tai-o-loos'	Name applied to Guichon Creek	
Tahoo-whéls'	Choo-whéls' Mountain	Many ravines.
Tshu-tshu	Murray Creek	

Indian Name.	Name Adopted or Description of Place on the Map.	Meaning Given for Indian Name.
Tsi'-kwus-tum....	Câche Creek, lower part.....	Cracked rocks.
Tsil-tsâlt.....	Tsil-tsâlt Ridge.....	
Tsin-tsoon'-ko....	Tsi-tsoon'-ko Lake.....	Island lake.
Tsoo-tsin-wowh....	Lytton Mountains.....	Streams.
Tsoo-weh'.....	Texas Creek.....	The stream.
Tsot-in-ant-kwa....	Tsotin Lake.....	Rattlesnake lake.
Tsuk-a-ts'-tum....	Forks of Tranquille River.....	Red place (at fork).
Tsuk-tsuk-kwâlk'.	Reservation on North Thompson.....	Red place (trees).
Tsuk-ôx.....	One of the Red Lakes.....	Red lake.
Tuk-a-mukên'.....	At head of Criss Creek.....	Bare ground.
Tuk-too'-la-hum....	Tuk-too'-la-hum Lake.....	Saline.
Wâ-lia.....	Napier Lake.....	
Za-kwas-ki.....	Za-kwas-ki Mountain.....	Dead.
Zia'-lot.....	Black Hill Creek.....	Round prairie.

(2.) Names of Inhabited Villages on the Kamloops sheet.

Indian Name.	Name Adopted, or Description of Place on the Map.	Meaning Given for Indian Name.
Kam-a-loo'-la-pa..	Kamloops.....	Point between the rivers.
Stlahl.....	Cornwall's.....	
Ne-whuh-wât'-tin-e-kin.....	4 miles above Câche Creek.....	
Pu-kaist'.....	1½ mile above Pukaist Creek.....	White.
N'-kam-sheon.....	Spence's Bridge.....	
Ti-kam-sheon.....	Lytton.....	
Ni-kai'-a.....	Opposite Lytton.....	
Stâ-zî'-in.....	Stein Creek.....	
Nes-i-kip.....	Opposite Foster Bar.....	
Kan-lax.....	Bridge River.....	The point.
Huh-ilp'.....	Fountain.....	On the edge.
Skwai'-luh.....	Pavilion Creek.....	Hoar-frost.
Kwâ-kwe-a-kwât'.....	11 miles above Kelley Creek.....	Blue.
Pil-ts'-uk.....	Clinton.....	White earth.
E-kuh-kah'-sha-tin.....	Pass Valley near Deadman River.....	Drying place.
Ski-shis-tin.....	Deadman River.....	
Sh-ha-ha-nih.....	Skuh'-un Creek.....	
N'-kah-li-mil-uh....	Mouth of Upper Nicola River.....	
Spa'-ha-min.....	Douglas Lake.....	Scraped.
Tsuk-tsuk-kwâlk'.	North Thompson.....	Red place.

APPENDIX III.

NOTES ON THE UPPER AND LOWER LIMITS OF GROWTH OF SOME TREES
AND OTHER PLANTS, IN DIFFERENT PLACES WITHIN THE AREA OF
THE KAMLOOPS MAP-SHEET.

The subjoined observations are principally of interest in their bearings on the climatic features of the region to which they relate. In this connection reference may be made to pages 14 B, 15 B of the foregoing report.

PSEUDOTSUGA DOUGLASHII (Douglas fir). Greatest heights at which this tree has been observed in various parts of the Kamloops sheet. *

	Feet.
East slope Cairn Mountain	5,750
South-east slope Mount Murray	5,750
Pass, Pavilion Creek to Maiden Creek.	5,590
North of Za-kwaski.....	5,450
As-kom Mountain.....	5,430
East side Forge Mountain	5,350+
West slope Choo-whels.....	5,290
Head of Hat Creek (south slope).....	5,220+
Arrowstone Hills.....	5,150
Cinder Hill (Highland Valley).....	5,070+
South-west slope Lytton Mountains.....	4,860
North " ".....	4,840
Pimainus Creek.....	4,780
Plateau, east of Deadman Lake (abundant).....	4,500
East slope Botanie Mountains.....	4,220
Plateau east of Young Lake (abundant).....	4,200

Though not abundant in the lower and drier valleys of the region the Douglas fir may be described as extending uninterruptedly downward from the levels above given to the sea-level.

PINUS PONDEROSA (Yellow pine).—Greatest heights at which this tree has been observed in various parts of the Kamloops sheet.—

	Feet.
North of Za-kwaski.....	5,300
Head of Hat Creek (south slope).....	5,200
East slope Marble Mountains, north of Clinton Creek.....	5,100
Head of Maiden Creek.....	4,960
East slope Cairn Mountain	4,800
Clinton Creek.....	4,670

*Where marked †, it is not quite certain that the actually highest limit was observed.

	Feet.
North slope, Lytton Mountains.....	4,340
West of Clapperton Creek (east slope).....	4,300
Timpanus Creek.....	4,190
East of Skuh'un Creek (south slope).....	4,170
East-west slope of Lytton Mountains.....	4,060
Highland Valley.....	4,000+
Hills above Leon Creek.....	3,930
La-loo-wissin Creek.....	3,830
Trail, Nicoamen to Nicola River.....	3,770
Hart Ridge (north slope).....	3,530
Above Young Lake.....	3,500
Criss Creek.....	3,370

This pine is particularly characteristic of the lower and drier valleys and their slopes. It extends down the Fraser Valley about as far as North Bend Station (487 feet) and there ceases only because of the increasing moisture of the climate on approaching the coast.

PINUS ALBICAULIS, (White-barked pine). *Least* elevations at which this tree has been observed in the Kamloops sheet.—

	Feet.
East side Clear Mountains.....	5,750
East side Chi-poo-in Mountain.....	5,610
Pass between La-loo-wissin and Hat Creeks.....	5,480
As-kom Mountain.....	5,400
Botanie.....	5,400
Lytton Mountains (north slope).....	5,340
North slope Nicoamen Plateau.....	5,300
East end Nicoamen Plateau.....	5,170
Stein Mountain.....	5,000
Ascending Coast Range towards Kl-ow'-a Mountain.....	4,900
Prospect Creek (south part of Nicoamen Plateau).....	4,450

From such heights as those above stated, this tree extends upward to the timber-line, but it is most abundant and characteristic between about 5500 and 6000 feet, in the region lying immediately to the eastward of the Coast Ranges, and characterized at such elevations by an alpine, but relatively dry climate. Within the limits of the Kamloops sheet, its geographical area may be thus defined:—To the west, bounded by a line following the higher summits of the Coast Ranges, to the east, by a line including Pavilion Mountains, following Hat Creek southward, including Mount Murray and thence following the Nicola Valley to the southern edge of the map. A very few specimens were, however, seen on the summits of Cornwall Hills to the east of this line.

ABIES SUBALPINA, (Mountain fir). *Least* elevations at which this tree has been observed in the Kamloops sheet.

	Feet.
Pass between La-loo-wissin and Hat Creeks.....	5,480
Plateau above Jamieson Creek (abundant).....	3,800
Botanie.....	3,660
Ascending Coast Ranges toward Kl-ow'-a Mountain.....	3,500

From such heights as those above stated, this tree extends upward to the timber-line, at about 7000 feet.

RHODODENDRON ALBIFLORUM. Least elevations at which this shrub has been observed in the Kamloops sheet.—

	Feet.
East end Nicoamen Plateau.....	5,170
Lytton Mountains (north slope).....	5,140
Plateau, head of Jamieson Creek.....	4,800
Plateau, head of Skull Creek (in shade).....	4,500
Ascending Coast Range towards Kl-ow'-a (in shade).....	4,300

From such heights, this form extends upward nearly to the timber-line.

PINUS MURRAYANA (Black pine)—This tree occurs in greater or less abundance in all parts of the Kamloops sheet, and at all elevations up to the timber-line. It is, however, most characteristic of the plateau at heights of 4000 or 5000 feet, where it frequently forms extensive forests. In the lower dry valleys it is scarce.

PICEA ENGELMANNI (Engelmann's spruce)—This tree is found nearly everywhere in the area of the Kamloops sheet, extending upwards to the timber-line, but is most characteristic of the higher plateaux and is seldom seen in the lower valleys.

TSUGA MERTENSIANA (Western hemlock)—This tree is very seldom found within the limits of the Kamloops sheet, where the climate appears not to be sufficiently humid for its healthy existence. It was observed at a height of 4000 feet in ascending the Coast Ranges, toward Poo-ytl Mountain, and is probably not uncommon at or above this height in the part of the Coast Ranges included by the map.

PINUS MONTICOLA (Western white-pine)—This tree also occurs very sparingly within the limits of the Kamloops sheet. It was observed at a height of 4200 feet in ascending the Coast Ranges towards Poo-ytl Mountain.

THUYA GIGANTEA (Western cedar)—This tree was observed in a few places within the limits of the map, but never attaining a large size. It is confined usually to narrow and shaded valleys, where considerable moisture is to be found. It was noted on the North Thompson

above the Fish-trap Rapid, on Edwards Creek, near the eastern limit of the map, at Botanie and near the east end of the Nicoamen Plateau a little beyond the south edge of the map.

LEDUM GLANDULOSUM.—Found on the plateau near the head of Skull Creek, at an elevation of 4500 feet, on the plateau near the Middle Fork of Tranquille River, at a similar elevation, and on the plateau near Spaist Mountain, between 4500 and 5000 feet.

PACHYSTEMA MYRSINITES was observed to be abundant on Botanie Mountain, on the Lytton Mountains, and on the eastern part of the Nicoamen Plateau, but not elsewhere within the limits of the sheet.

EVERNIA VULPINA.—This bright yellow lichen, growing upon trees, is generally abundant at heights exceeding 3000 feet, but it was observed in abundance at exceptionally low elevations in the Twaal Valley (2740 feet) and in the Venable Valley (2230 feet).

APPENDIX IV.

COMPARATIVE OBSERVATIONS OF TEMPERATURES AT DIFFERENT ALTITUDES IN OR NEAR THE REGION EMBRACED BY THE KAMLOOPS SHEET, SOUTHERN INTERIOR OF BRITISH COLUMBIA, DURING PARTS OF THE YEARS 1888, 1889 AND 1890.

TABLE I.—A summary of minimum temperatures grouped according to altitudes and compared with the minima observed during the same nights at Kamloops.

TABLE II.—Temperatures observed at 9 p.m. at various altitudes, compared with simultaneous observation at Kamloops.

NOTE.—In the column headed "Difference" + means higher and — lower than at Kamloops. The height of Kamloops above the sea is 1150 feet. In the pages following the tables, the observations are given in detail, with the actual elevation and locality of each.

The observations made at 9 p.m., appear to show that, soon after sunset, the effect of nocturnal radiation in lowering the temperature increases almost uniformly to the greatest heights represented. The minimum temperatures likewise show a nearly regular decrease with increased height, up to between 4000 and 5000 feet, beyond which, for 2000 feet or more (to the greatest heights represented) this ceases, and the difference as compared with Kamloops remains nearly constant.

As compared with the normal vertical temperature gradient of the atmosphere (1° F. to 300 feet) the minima are some 5° too low at about 4500 feet and nearly 3° too high at 6500 feet. This anomaly may be explained by the existence of considerable areas of plateau country up to nearly 5000 feet, while the areas standing above 5000 feet are relatively small. It may also be connected with the general inflow of air from the west, across the Coast Ranges, maintaining a nearly constant temperature when little in contact with radiating land surfaces. Mr. R. F. Stupart, Director of the Meteorological Service, informs me that such an inflow, during the summer months, is indicated by the mean barometric gradients and that the years 1889 and 1890 were nearly normal in this respect.

TAB.

TEMPERATURE IN RELATION TO ALTITUDE.
 MINIMUM Temperatures observed at various altitudes, compared with

Month and Year.	Altitudes under 1000'.				Altitudes 1000'-2000'.				Altitudes 2000'-3000'.				Altitude	
	No. of observations.	Mean.	Corresponding mean at Kamloops.	Difference.	No. of observations.	Mean.	Corresponding mean at Kamloops.	Difference.	No. of observations.	Mean.	Corresponding mean at Kamloops.	Difference.	No. of observations.	Mean.
1888.		°	°	°		°	°	°		°	°	°		°
July.....	1 49	52.2	-3.2						4 38.2	56.5	-18.3		12 35.6	
1889.														
July.....					4 55.5	61.77	-6.27	13 47.4	57.4	-10			4 43.1	
Aug.....					2 39.7	52.1	-12.4	6 47	56.7	-9.7			5 45.5	
Sept.	6 41.8	39.9	+1.9		7 48.8	47	+1.8	1 43	43.9	-0.9			7 35	
Oct . . .	1 49	41.9	+7.1		2 46.5	43.4	-2.9	3 30.7	39	-8.3			16 32.7	
1890.														
June.....									1 43.5	50.3	-6.8		4 38.1	
July.....	2 52.5	51.95	+0.55		1 50	54	-4	2 45	56.85	-11.85			1 36	
Aug.....					4 41.3	53.0	-11.7	2 48.5	59.65	-11.15				
Sept.					7 39.8	42.5	-2.7	5 35.1	42.84	-7.74			8 36	
Oct.....					5 41.2	40.7	+0.5	1 42	45.2	-3.2				
	10 45.38	38.54	+6.84	32	44.49	47.87	-3.38	38	43.02	53.08	-10.06	37	6.35	

TAB.

LE I.

IN RELA
tion to ALTITUDE.

tion to ALTITUDE.

the minima observed during the same nights at Kamloops, B.C.

Altitudes 3000'-4000'.		Altitudes 4000'-5000'.		Altitudes 5000'-6000'.		Altitudes 6000'-7000'.	
Corresponding mean at Kamloops.	Difference.	No. of observations.	Mean.	Corresponding mean at Kamloops.	Difference.	No. of observations.	Mean.
54.4	-15.8	1	31	55	-24	1	43
55.1	-12	1	31	55	-24	1	43
54.25	-8.75	6	34	54.4	-20.4	1	31
45.7	-10.7	1	41	50.6	-9.6	1	34
44.2	-11.5	3	33.1	50.1	-17	1	31
56.7	-18.6	5	28.6	49.5	-20.9	1	31
54.8	-18.8	1	48	62	-14	5	37.5
50.15	-14.15	2	29	41.2	-12.2	1	28
50.08	-13.73	22	33.77	51.85	-18.08	15	36.0
51.5	-15.3	7	35.2	50.2	-15.0	1	31

TAB

TEMPERATURE IN RELA

TEMPERATURES observed at 9 p.m. at various altitudes, compared

Month and Year.	Altitudes under 1000'				Altitudes 1000'-2000'				Altitudes 2000'-3000'				Altitud	
	No. of observations.	Mean.	Corresponding mean at Kamloops.	Difference.	No. of observations.	Mean.	Corresponding mean at Kamloops.	Difference.	No. of observations.	Mean.	Corresponding mean at Kamloops.	Difference.	No. of observations.	Mean.
1880.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July.....					3	69	79.1	-10.1	14	62.8	80.5	-17.7	4	56.2
August.....					2	67.5	68.8	-1.3	5	59.6	70.7	-11.1	5	54.2
Sept.....	6	50.8	49.5	+1.3	7	60	60.3	-0.3	1	55	61.9	-6.9	6	40.4
Oct.....	1	55	59.2	-4.2	2	48.5	51.5	-3	3	38	42.4	-4.4	14	40.5
1890.														
June.....					1	64	73	-9					4	50.6
July.....	1	59	58.9	+0.1					1	68	79.1	-11.1		
Aug.....					5	59.4	66.4	-7	1	56	70.7	-14.7		
Sept.....					9	51.5	56.5	-4	5	49.8	59.7	-9.9	7	44.1
Oct.....					3	48	47.5	+0.5	1	46.5	49.3	-2.8		
	8	52.25	51.9	+0.45	32	57.1	61.0	-3.9	31	64	69.9	-5.9	40	45.4

LE II.

TION TO ALTITUDE.

with the observations made at the same time at Kamloops, B.C.

compared

0000' Altitude			es 3000'-4000'. Altitudes 4000'-5000'.			Altitudes 5000'-6000'.			Altitudes 6000'-7000'.							
Difference.	No. of observations.	Mean.	Corresponding mean at Kamloops.	Difference.	No. of observations.	Mean.	Corresponding mean at Kamloops.	Difference.	No. of observations.	Mean.	Corresponding mean at Kamloops.	Difference.				
0	0	0	0	0	0	0	0	0	0	0	0	0				
17.7	4	56.2	65.8	-19.6	7	46.3	66.5	-20.2	1	45	63.3	-18.3	3	37.8	60.9	-23.1
11.1	5	54.2	51.3	-10.9	1	49	58.5	-9.5	1	44	50	-15	2	41.5	60.3	-18.8
0.9	6	40.4	46.4	-5.9	3	43.3	54.6	-11.3								
4.4	14	40.5	67.8	-17.2	5	42.1	60.9	-18.8								
...	4	50.6	...	...	1	46	72	-26	4	39.2	58.7	-19.5	2	43.5	62.5	-19
11.1	...	...	...	...	3	46.7	62.3	-15.6	2	42	68.1	-26.1				
14.7	...	...	59.2	-15.1	2	40.5	53.1	-12.6	1	45	58.8	-13.8				
9.9	7	44.1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5.9	40	45.4	56.57	-11.17	22	44.57	61.7	-17.13	9	41.6	61.3	-19.7	7	40.5	61	-20.5

TEMPERATURE OBSERVATIONS.*

Date.	Altitude.	Minimum temperature.	Corresponding Minimum at Kamloops.	Difference.		Locality.
1888.	Ft.	°	°	°	°	
July 4.....	3920	41	50	- 9	.....	Head of Guichon Creek.
" 5.....	3920	40	51	-11	.....	"
" 6.....	3300	31	47.4	-16.4	.....	Mamit Lake.
" 7.....	3300	33.5	49.3	-15.8	.....	"
" 8.....	3470	33.5	52.5	-19	Max., 86.5	Wiches Brook.
" 9.....	3470	40	56.3	-16.3	.....	"
" 10.....	3870	30	58	-26	.....	Highland Valley.
" 11.....	900	49	52.2	- 3.2	.....	Mouth of Pimainus Creek.
" 14.....	2690	35	52	-17	.....	Skuh-un' Creek.
" 15.....	3150	30	52.6	-22.6	Max., 75	Guichon Creek.
" 16.....	3150	37.5	59.6	-22.1	.....	"
" 19.....	3500	52	59	- 7	.....	Prospect Creek.
" 22.....	3100	28.5	58.5	-30	Max., 92.5	Head of Otter River.
" 23.....	3100	31	62	-31	.....	" "
" 24.....	2530	39	58.9	-19.9	.....	Otter Flat (Campmen' des Femmes)
" 25.....	2440	39	57.1	-18.1	.....	Opposite Granite Creek.
" 26.....	2530	40	58.2	-18.2	.....	Otter Flat.
" 27.....	5400	35.5	47	-11.5	.....	Old Brigade Trail.
" 29.....	5200	40	59.8	-19.8	.....	Near Upper Tulameen.
" 30.....	5200	31.5	47.5	-16	.....	" "
" 31.....	6200	39	49	-10	.....	Near Loadstone Mountain.
Aug. 1.....	2800	51	.....	.....	.....	Rabbit's Store, Tulameen.

*Altitude of Kamloops, 1150 feet.

TEMPERATURE OBSERVATIONS.*

Date.	Altitude.	Minimum temperature.		Corresponding minimum at Kamloops.	Difference.		Time and Temperature.	Temperature at 9 p.m.	Corresponding temperature at Kamloops.	Difference.	Locality of minimum and morning reading.
		°	Ft.	°	°	°					
1889.											
July 1.....	3970	42	50.7	°	- 3.7	°	a.m. 6	53	67	- 14	Loon Lake camp.
" 2.....	2180	39	51.5	°	- 12.5	°	7.15	59	72.3	- 16.3	Deadman River.
" 3.....	2180	44	55.9	°	- 11.9	°	6	68	78.9	- 10.9	"
" 4.....	2520	42	58.5	°	- 11.5	°	6	60			Isotin Lake.
" 5.....	1130	52	52	°	0	°	8	55	58.9	- 2.9	Savona.
" 6.....	2410		47.9	°		°	7	52	66.9	- 16.9	South of Penny's.
" 7.....	3974	44	57	°	- 13	°	9 a.m. 7.4	52	61.9	- 9.9	Slope of Mt. Glossy.
" 8.....	3974	39	50.2	°	- 11.2	°	6.30	40			"
" 9.....	5550	43	51	°	- 8	°	6	44	70	- 14	Mt. Glossy.
" 10.....	2200	50	55	°	- 5	°	7.15	64			South of Penny's.

*Note.—The minimum temperature and the morning observation in each case correspond with the altitude given in the same line of the table. The evening observation, however, corresponds with the altitude given in the next line below, the camp having been moved in the course of the day.

TEMPERATURE OBSERVATIONS—Continued.

Date.	Altitude.	Minimum temperature.	Corresponding minimum at Kamloops.	Difference.	Time and Temperature.	Temperature at 9 p.m.	Corresponding temperature at Kamloops.	Difference.	Locality of minimum and morning reading.
1880.	Ft.	°	°	°	a.m.	°	°	°	
July 11.....	.....	.....	53.5	.....	.....	63	73.9	-10.9	Kamloops Lake.
" 12.....	2130	52	56	-4	6.20 56	45	78	-33	Duffy Creek.
" 13.....	4130	31	55	-24	6.20 40	.....	.....	.....	Upper Cherry Bluff Creek.
" 15.....	.....	.....	.....	.....	.....	63	77.5	-14.5	Kamloops.
" 16.....	1850	55	66.9	-11.9	6.15 70	60	66.5	-6.5	Reservation Creek.
" 17.....	2800	49	60.7	-11.7	6.15 59	59	73	-17	Edwards Lake.
" 18.....	2950	50	60.1	-10.1	6 51.5	70	80	-10	Head of Louis Creek.
" 19.....	1240	.....	.....	.....	8 78	74	79.9	-5.9	Near Pemberton's Ranch.
" 20.....	1240	60	65.7	-5.7	6.30 66	61	73	-12	" "
" 21.....	2500	45	54.5	-9.5	8 69	84	73	+11	Near South Thompson.
" 22.....	2500	44	53.8	-9.8	8 54	.....	.....	.....	" "
" 25.....	1990	55	62.5	-7.5	6 53.5	68	80.9	-12.9	Campbell Creek.

" 26

2220

53

64.1

-11.1

6

59

54

79

-25

Newman's

" 27

3700

47.5

62.7

-15.2

5.45

49

60

81

-21

" 28

" 29

" 30

" 26	2220	53	64.1	-11.1	6	59	54	79	-25	Newman's
" 27	3700	47.5	62.7	-15.2	5.45	49	60	81	-21	West of Brigade Lake.
" 28	2480	44.5	61.6	-17.1	7.10	64	69	80.3	-11.3	Dropping water Creek.
" 29	2900	57	62.4	-5.4	8.30	69	69	75.6	-6.6	Scott Creek.
" 30	3542		61		8	61	66.5	77.9	-9.4	Nuon, 82°.
" 31	2630	47.5	57.9	-10.4	6	52	58	74	-16	Douglas Plateau.
Aug. 1	2020	44	54.8	-10.8	7	52	64	68.5	-4.5	Above Douglas Lake.
" 2	2020	49	55.9	-6.9	6	51	68	78.9	-10.9	Nicola Lake.
" 3	2020	52	58.6	-6.6	6.45	60	65			Quichenna.
" 4	2100	46.5	59	-12.5	8	58	58	66.2	-8.2	Clapperton's.
" 5	2100	45.5	50.1	-13.6	6.30	54	65	64.8	+2	Guichon Creek.
" 6	1700	35	50	-15	8	59	55	66.4	-11.4	"
" 7	3120	46	56	-10	7	49	45	63.3	-18.3	Nicola River.
" 8	5560	31	49	-18	6.50	44	41	67.3	-26.3	Trail to Za-kwaski Mt.
" 9	6180	35	51.1	-16.1	8.15	65	44			"
" 10	6180	44			7	52	60	65.9	-5.9	Za-kwaski camp.
" 11	3350	48	51.9	3.9	7	54	70	72.8	-2.8	"
" 12	1400	44.5	54.4	-9.9	6.30	59	55	73.4	-18.4	Near Agate Creek.
" 13	4800	31.5	57.1	-25.6	8	61	44	73	-29	Nicola River.
" 14							46	56.3	-10.3	Pimainus Lake.
" 15										Botanie.

TEMPERATURE OBSERVATIONS—Continued.

Date.	Altitude.	Minimum temperature.	Corresponding minimum at Kamloops.	Difference.	Time and Temperature.	Temperature at 9 p.m.	Corresponding temperature at Kamloops.	Difference.	—	Locality of minimum and morning reading.
1889.	Ft.	°	°	°	a.m.	°	°	°		
Apr. 19.	3610	43	52.5	- 9.5	7.45	50	66.3	- 16.3		Botanie.
" 20	2940	45	53	- 8	8	48				Skoon-ko' Creek.
" 21	790		51.7			59	79.1	- 20.1		Spence's Bridge.
" 22	3190	50	52.9	- 2.9	7	53	73.9	- 20.9		Murray Creek.
" 23	4510	35	54	- 19	9	49	55.8	- 16.8		Murray Mountain camp.
" 24	4510	32	46	- 16	8	39	64.8	- 19.8		" "
" 25	4510	36	54.5	- 18.5		45	66.9	- 21.9		" "
" 26	4800	33	57.5	- 24.5	6.45	39	58.2	- 15.2		Head of Hat Creek.
" 27	4480	37	55.9	- 18.9	7.40	45	55.2	- 21.7		Blue-earth Creek.
" 28	6310	28.5	50.2	- 21.7	7.45	33.5	69.4	- 21.4		Cairn Mountain camp.
" 29	6610	37	55	- 18	7	43	70	- 19		Hat Creek.
" 30	3470	40.5	57.9	- 17.4	7	45				

Sept.	2											52	-13	
		3480	37	55.9	-18.9	7.40	45	33.5	55.2	-21.7	39			
"	3	3480	37	55.9	-18.9	7.40	45	33.5	55.2	-21.7	39	48.9	-4.9	Cornwall's.
"	4	3080	31	39.4	-8.4	7.45	45	39	60.4	-21.4	54	64	-10	McLean Lake.
"	5	3080	51	56.4	-5.4									Medicine Creek.
"	6	3080	39	51.5	-12.5	7	49	43	61.6	-18.6	43	61.6	-18.6	"
"	7	6220	34	47	-13	7.30	41	40	59.1	-19.1	40	59.1	-19.1	"
"	8	6220	30 (1)	44.9	-14.9	7.40	28	33.5	45.3	-12.3	33.5	45.3	-12.3	Chi-poon camp.
"	9	3120	31	38	-7	8	33	35	44.3	-9.3	35	44.3	-9.3	"
"	10	3120	29.5	40.9	-11.4	7.25	32	50	44.6	+5.4	50	44.6	+5.4	Three-lake Valley.
"	11	800	40.5	40.1	+4	7.40	43.5	50.5						"
"	12	640	42	40.5	+1.5	7.40	47	41	40.9	+1	41	40.9	+1	Rock-slide camp.
"	13	640	34	36	-2	8	40	53.5	45	+9.5		45	+9.5	Lillooet camp.
"	14	780	48.5	39.8	+8.7	8	40							"
"	15	780												Bridge River.
"	16	780						59	55.1	+3.9		55.1	+3.9	"
"	17	940	46	46.5	-5	7	52	64	62.1	-11.1		62.1	-11.1	"
"	18	1740	52	50	+2	7	56	70	66.1	-2.1		66.1	-2.1	Spring camp opposite Foun- tain.
"	19	1250	60	46.2	+13.8	7.10	60	68	65.1	+4.9		65.1	+4.9	Opposite Pavilion Creek.
"	20	1540	52	45.5	+6.5	7	53	56	60.3	+7.7		60.3	+7.7	Above Leon Creek.
"	21	1086	46.5	52	-5.5	8	51.5	55	63.6	-7.6		63.6	-7.6	Camp above Watson Creek.
									57.7	-2.7		57.7	-2.7	Leon Creek.

Watson Creek.

Cairn Mountain camp.

Hat Creek.

TEMPERATURE OBSERVATIONS—Continued.

Date.	Altitude.	Minimum temperature.	Corresponding minimum at Kamloops.	Difference.	Time and Temperature.	Temperature at 9 p.m.	Corresponding temperature at Kamloops.	Difference.	—	Locality of minimum and morning reading.
1889.	Ft.	°	°	°	a.m.	°	°	°		
Sept. 22	1740	43	49.3	- 6.3	{ 8.15 52 } { 2 p. 55 }	52	51.7	+ 3	Max., 64°	Opposite Pavilion Creek.
" 23	1740	44	45	- 1	{ 7.15 a. 50.5 } { 7 a.m. 44 }	46	49.3	- 3.3	"	"
" 24	700	40	36.8	+ 3.2	7 a.m. 44	50				1 mile below Bridge R.
" 25	1077	40.5 at 6.25 a.	38.4	.....	7.20 40.5	55	57.7	- 2.7		Fountain Creek.
" 26	1640	44	41	+ 3	7.25 45.5	55	61.9	- 6.9		18-Mile Creek.
" 27	2300	43	43.9	- .9	7.20 49	49	58.5	- 9.5		Pavilion Creek crossing.
" 28	4380	41	50.6	- 9.6	7.10 47.5	44	59	- 15		Upper Pavilion Creek.
" 29	5480	34	51.5	- 17.5	7.30 36	37	57.1	- 20.1		Pavilion Mountains.
" 30	3120	37	49.9	- 12.9	7.40 43	36	51	- 15		Glen Hart.
Oct. 1	3120	33	59	- 26	8 35	36				"
" 2	3090	30	47	- 17	8 41	42	56	- 14		Clinton.
" 3	3600				8 45	40	53	- 13	2 p., 50°	Kelley Lake camp.

Oct. 1	3120	33	59	-25.5	7.40	41	55	59.2	-4.2	"	"
" 2	3000	30	47	-17	8	41	42	56	-14	Clinton.	Clinton.
" 3	3500				8	45	40	53	-13	2 p., 50°	Kelley Lake camp.
" 4	3600	31.5	57	-25.5	7.40	41	55	59.2	-4.2	"	"
" 5	940	49	41.9	+7.1	7.40	49.5	56	60.8	-4.8	Camp opposite Lean Creek.	Camp opposite Lean Creek.
" 6	1720	50	47.6	+2.2	7.45	54	51	58.3	-7.3	Cascade camp	Cascade camp
" 7	3300	35	46	-11	8	40	46	56.2	-10.2	Haller's Mill.	Haller's Mill.
" 8	4620	33	52.9	-19.9	7.40	34	42			Head of Kelley Creek.	Head of Kelley Creek.
" 9	3200	38	49.3	-11.3	7.10	39				Kelley Lake camp.	Kelley Lake camp.
" 10	3000	41	49.3	-8.3	9	42.5	39	50.4	-11.4	Clinton.	Clinton.
" 11	3000	38	43	-5	8	42	36.5	52.4	-5.9	"	"
" 12	4850	35	49.9	-14.9	7.45	40	47.5	55.3	-7.8	Head Clinton Creek.	Head Clinton Creek.
" 13	4160	31.5	47.5	-16	7.15	33	32	53.3	-1.3	Head Sandy Creek.	Head Sandy Creek.
" 14	3600	33	45	-12	8	34	28	45.8	-17.8	Big Bar Lake.	Big Bar Lake.
" 15	3600	20	32.9	-12.9	8	23	30	42	-12	"	"
" 16	3800	21	33.5	-12.5	8	32	34.5 p. 35.5 p.	43	-7.5	Boyd's 70-Mile House.	Boyd's 70-Mile House.
" 17	3800	26.5	38	-11.5	7.30	32	36	40	-4	Green Lake.	Green Lake.
" 18	2050	27	35.5	-8.5	7.30	30	34	40.4	-6.4	Bonaparte River.	Bonaparte River.
" 19	2340	28	34	-6	7.30	30	37	43	-6	"	"
" 20	3120	31	39.5	-8.5	8	34	41	42.3	-1.3	Glen Hart.	Glen Hart.
" 21	1800	31	39	-8	7.30	41	44	47	-3	Bonaparte at Hat Creek.	Bonaparte at Hat Creek.
" 22	2600	37	47.4	-10.4	7.30	42	44	48.9	-4.9	Tsotin Lake.	Tsotin Lake.
" 23	3515	42	47.9	5.9	7.30	43	39	50.9	-11.9	Summit camp.	Summit camp.

TEMPERATURE OBSERVATIONS—Continued.

Date.	Altitude.	Minimum temperature.	Corresponding minimum at Kamloops.	Difference.	Time and temperature.	Temperature at 9 p.m.	Corresponding temperature at Kamloops.	Difference.	—	Locality of minimum and morning reading.
	Ft.	°	°	°	a.m.	°	°	°		
1899.										
Oct. 21.....	3200	37	43.2	- 6.2	7.20 41	40	46.6	- 6.6	.....	Upper Tranquille R.
" 22.....	3500	33	36.2	- 3.2	8 40	44	47.2	- 3.2	.....	Middle Fork Tranquille.
" 26.....	3500	33.5	40.6	- 7.1	7 34	..	.....	.....	.....	"
1890.										
June 19.....	2780	43.5	50.3	- 6.8	6 51	35	57.6	- 22.6	.....	Jacko Creek.
" 20.....	4100	26.5	45	- 18.5	6.30 39	9.35 p.	.....	.....	.....	Trout Lake.
" 21.....	5850	31.5	49	- 17.5	.....	38	59.3	- 21.3	.....	Choo-whels Mountain.
" 22.....	4890	25	48.6	- 23.6	7 42	9 p.	67.8	- 16.8	2 p.m., 67°	Face Lake.
" 23.....	4100	35.5	53.5	- 18	8.40 44.5	43	58.7	- 15.7	.....	Meadow Creek.
" 24.....	4100	28	52.5	- 24.5	.....	43.5	61	- 17.5	Max., 66°	"
" 25.....	4100	28	48	- 20	.....	50.5	65	- 14.5	.....	"
" 26.....	3480	34	53.5	- 19.5	7.10 51	2.15 p.	63	- 15	.....	Witches Brook.
" 27.....	3450	35	53.4	- 18.4	.....	9 p.	70.9	- 18.9	.....	"

" 25.....	4100	28	48	- 20	7.10	51	9.15 P.	63	- 15	Witches Brook.
" 26.....	3480	34	53.5	- 19.5	7.10	51	9 P.	70.9	- 18.9	"
" 27.....	3450	35	53.4	- 18.4						"
July										
" 28.....	3900	38.5	50.7	- 21.2	12.30	75	52	72.5	- 20.5	Mo. Woods Creek.
" 29.....	3550	45	60.5	- 15.5				73	- 9	Near Pukaist Creek.
" 30.....										Tvaal Creek crossing
" 1.....	1700	50	54	- 4						"
" 2.....										Head Tvaal Creek.
" 3.....	2230	51	62.8	- 11.8			63 9.20 P.	79.1	- 11.1	Venable Valley.
" 4.....	4070	48	62	- 14	7	51	9 P.	72	- 26	Bear Spring.
" 5.....	3000	36	54.8	- 18.8						Botanic.
" 6.....	2880									Botanic Creek.
" 7.....	2950	39	50.9	- 11.9				58.9	+ .1	Max., 59°
" 8.....	500	53	50	+ 3				62	- 23	Lynton.
" 9.....	5880	35	53.5	- 13.5				54.9	- 15.9	Lynton Mountains.
" 10.....	5880	35	50.9	- 13.9	8	37	39	61	- 22	Max., 49°
" 11.....	5880							57	- 17	2.40 P., 40.5°
" 12.....	5880	36	52.5	- 16.5						Max., 88°
" 16.....	5930	40	50.9	- 10.9						"
" 17.....	5930	40.5	54.6	- 14.1						Kl-ow'a Mountain.
" 19.....										"
" 20.....	6880	34	47.9	- 13.9			42	59.9	- 17.9	Stein Mt.
" 21.....	6880	39	51.6	- 12.6			45	65.2	- 20.2	"

TEMPERATURE OBSERVATIONS—Continued.

Date.	Altitude.	Minimum temperature.	Corresponding minimum Kainloops.	Difference.	Time and Temperature.	Temperature at 9 p.m.	Corresponding temperature at Kainloops.	Difference.	Max., 97°.	Locality of minimum and morning reading.
1890.	Ft.				a.m.					
July 22.....										Stein Creek.
" 23.....	550	52	53.9	- 1.9						"
" 27.....						59	53.9	+ 5.9		Texas Creek.
Aug. 1.....	2400	51	60.2	- 9.2						Pavilion Creek.
" 2.....	1600					69	71.9	- 2.9		Bonaparte River.
" 3.....	1600	49	59.3	-10.3						"
" 6.....						61	64.9	- 3.9		Deadman River.
" 15.....						60	63.5	- 3.5		Fish-trap Rapid.
" 16.....	1200	40	47	- 7		55	64.3	- 9.3		"
" 17.....	1200	42	55.9	-13.9		52	67.6	-15.6		Barrière River.
" 18.....	1200	34.5	50	-15.5						Opposite Indian Reserve.
" 21.....	4070					46	62.5	-16.5		Eating Lake.

	1200	34.5	50	-15.5	46	62.5	-16.5			
" 18.	4070								Opposite Indian Reserve.	
" 21.									Eating Lake.	
" 22.	4070	34	53	-19		45	58	-13	"	
" 23.	4500	41	53	-12		49	66.3	-17.3	West of Stu Hill.	
" 24.	4900	43	59.6	-16.6					Near Poison Hil	
" 25.	5100	36	58.1	-22.1		44	70	-25	Poison Hill camp.	
" 26.	5480	29			7.20	40	66.2	-26.2	Caribon Lake.	Noon, 65°.
" 27.	5920	23	47.8	-14.8		32	63	-11	Porcupine Ridge.	
" 28.									"	
" 29.	2900	46	59.1	-13.1		56	70.7	-14.7	Lake LeBoia.	
Sept. 1	2600					50	53.3	-3.3	Peterson Creek.	
" 2	3500					43	53.4	-10.4	West of Brigade Lake.	
" 3	3500	39	49.5	-10.5		45	63	-18	"	
" 4						45	60.9	-15.9	Head of Moore Creek.	
" 5	3480	40	51.9	-11.9		39	57	-18	"	
" 6	2890	25	38.6	-13.6		48	53	-5	Moore Creek.	
" 7						53	62.3	-9.3	Scott Creek.	
" 8	2020	33	47.2	-14.2		50	65.6	-15.6	Nicola Lake.	
" 9	2000	33.5	41.9	-8.4		50			Douglas Lake.	
" 10	3020	40	48.8	-8.8		35	50.9	-15.9	Chaparon Lake.	
" 11	3020	21	33.5	-12.5		31	44.6	-13.6	"	
" 12	4200	17	31.5	-14.5		45	58.8	-13.8	South-east Chaparon Lake.	

TEMPERATURE OBSERVATIONS—Continued.

Date.	Altitudes.	Minimum temperature.	Corresponding minimum at Kamloops.	Difference.	Time and Temperature.	Temperature at 9 p.m.	Corresponding at Kamloops.	Difference.	—	Locality of minimum and morning reading.
1880.	Ft.	°		°	a.m.	°		°		
Sept. 13	5680	28	46	-18	7.45	50	61.7	-11.7		Okanagan Plateau.
" 14	4580	41	50.9	-9.9	...	59	61	-2		"
" 15	2830	41	44.5	-3.5	...	54	58.9	-4.9		Deep Creek.
" 16	1250	53	47.2	+5.8	...	60	57.5	+2.5		Okanagan Lake.
" 17	1250	54	47	+7.0	...	54	55	-1		"
" 18	1250	36	38.8	-8	...	59	49.6	+9.4		
" 19	1250	39	40	-1.0	...	49	55.9	-6.9		O'Keefe's.
" 20	1250	37	45	-8.0	8	6.30 p. 49	60.3	-11.3		Vernon.
" 21	1250	37	45	-8.0	8	9 p. 49	60.3	-11.3		Coldstream.
" 22	1550	42.5	...	...	7.15	45	59.3	-14.3		"
" 23	1680	28	41.4	-13.4	...	8.15 p. 48	54.3	-6.3		Near Slack's.
" 24	1460	32	40.2	-8.2	7.30	47	...	...		Shingle camp.

" 22	1550	42.5			7.15	48	45	59.3	-14.3	Cherry Creek Mines.
" 23	1680	28	41.4	-13.4			8.15 p.	54.3	-6.3	McIntyre's.
" 24	1460	32	40.2	-8.2	7.30	47	48			"
" 25	2480	43	42	+1	7.30	49	8.40 p.	63.1	-20.1	"
" 26	3860	35	47	-12	7.15	37	43	69.8	-21.8	"
" 27	3860	37	51	-14	8.15	42	48			"
" 28	3860	39	63.5	-24.5			8.30 p.	58.9	-13.4	"
" 29	3860	36	55	-19			8.45 p.	46.9	-9	Tom Slack's.
" 30	1680				7.30	54	8.39 p.	46		Coldstream.
Oct. 1	1630	37	41.6	-4.6			9 p.	46.6	+4.4	Long Lake.
" 2	1300	44	35.8	+8.2						"
" 3	1300	48	39	+9						Vernon.
" 4	1300	36	42	-6	8.15	43	47	48.9	-1.9	Salmon River.
" 5	1460	42	44.9	-2.9	8	44	44			Grande Prairie.
" 6	1900	41			8	46	46.5	49.3	-2.8	Noon, 51°
" 7	2200	42	45.2	-3.2						Near Monte Lake.

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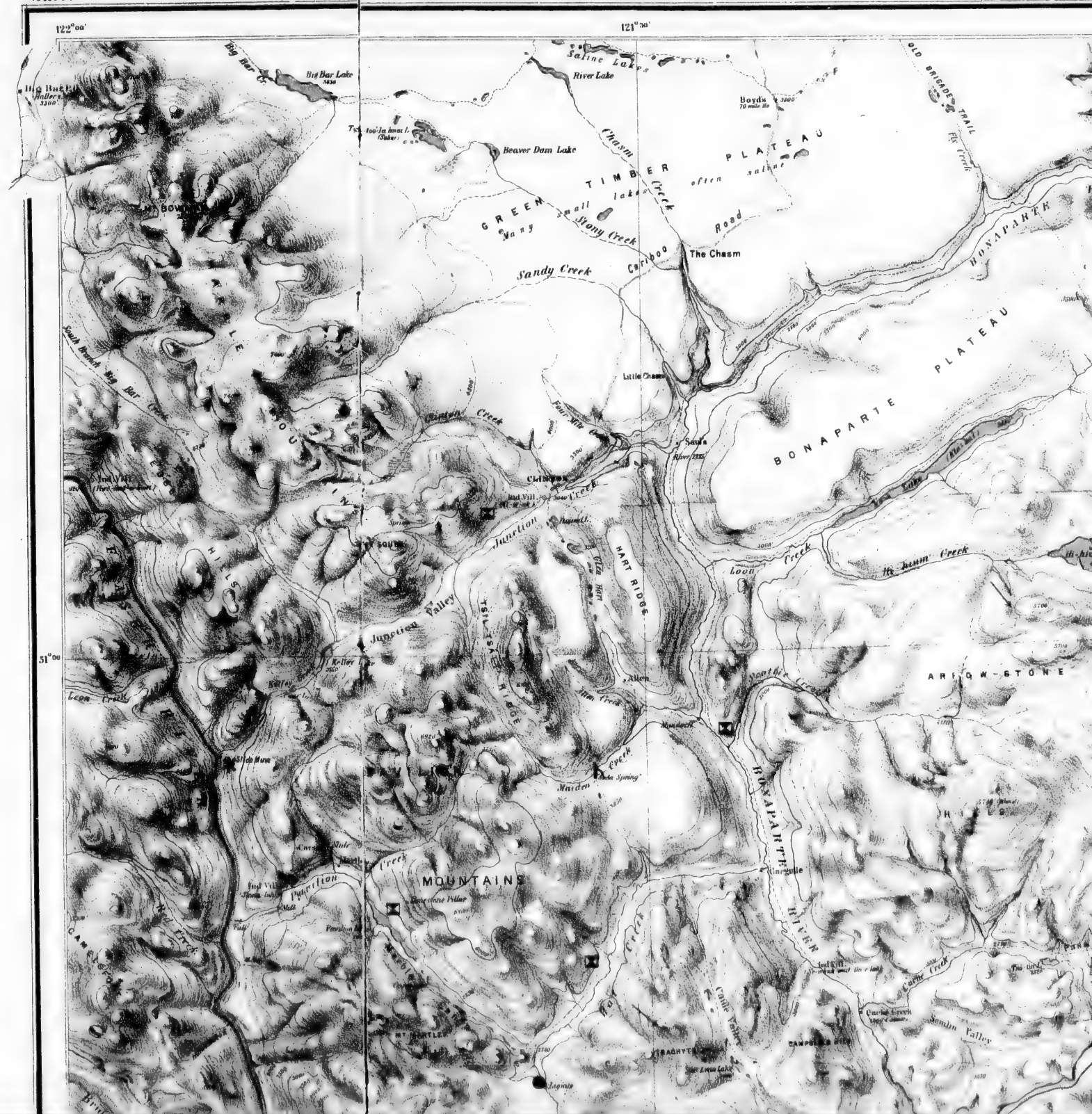
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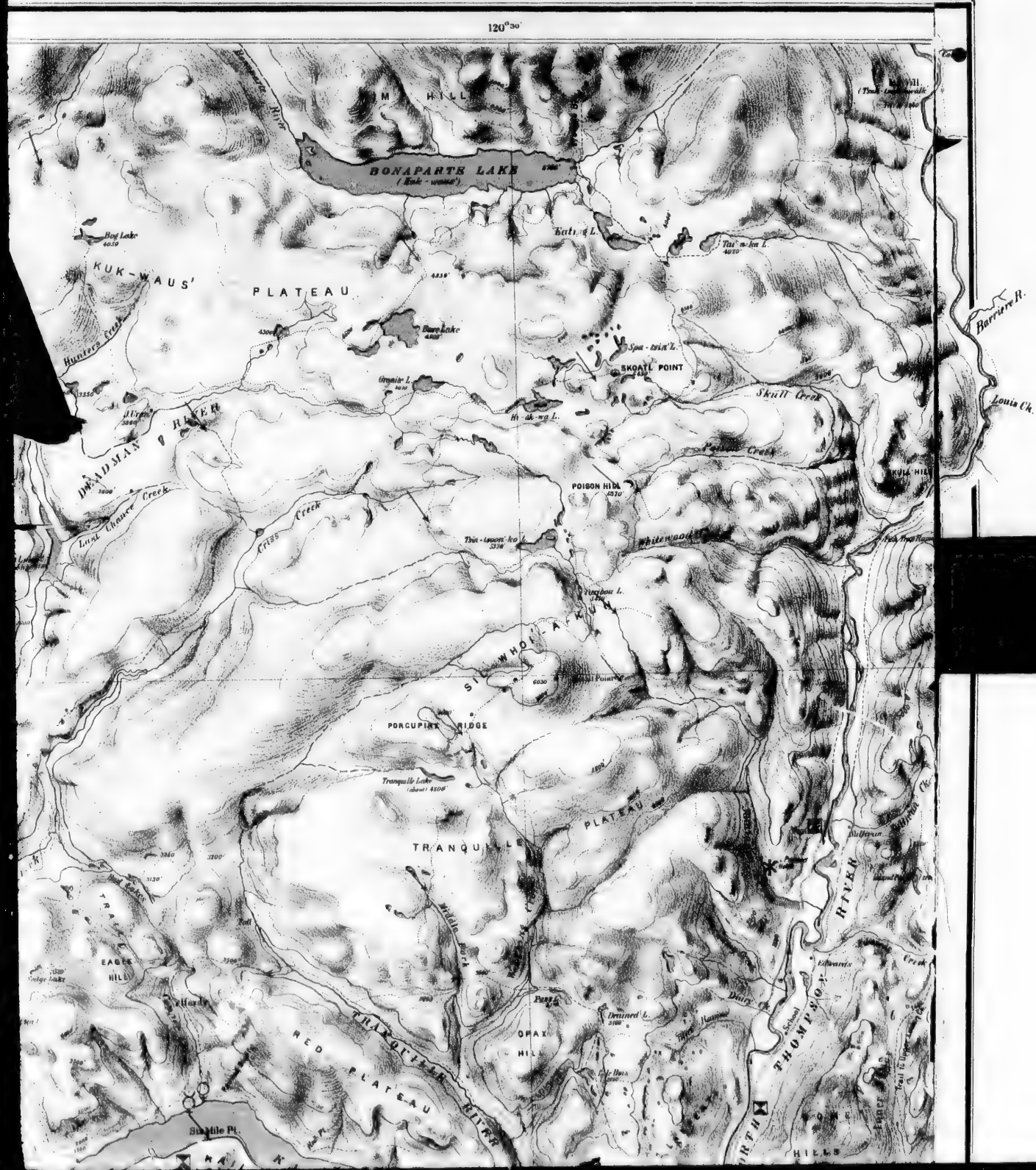
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This is a detailed topographic map of a region in Alaska, likely the Denali National Park area. The map is oriented with North at the top. Key features include:

- Topography:** The map shows a series of plateaus and ridges. At the top is the **BONAPARTE PLATEAU**, followed by **KUK-WAUS' PLATEAU**. Below these are the **POISON HILL**, **PORCUPINE RIDGE**, and **TRANQUILLE PLATEAU**. The bottom of the map shows the **RED PLATEAU** and **RED DOUBT HILLS**.
- Water Bodies:** **BONAPARTE LAKE** (labeled "Esk. wawa") is at the top. **Bog Lake** is on the left. **Denali Lake** is in the center. **Tranquille Lake** is below it. **Redoubt Lake** is at the bottom right. **Denali River** flows from the top left towards the center. **Klondike River** and **Klondike Creek** are also shown.
- Geographical Labels:** **POISON HILL**, **PORCUPINE RIDGE**, **TRANQUILLE PLATEAU**, **RED PLATEAU**, **RED DOUBT HILLS**, **Denali River**, **Klondike River**, **Klondike Creek**, **Bog Lake**, **Denali Lake**, **Tranquille Lake**, **Redoubt Lake**, **Denali Pt.** (at the bottom left).
- Elevations:** Numerous elevation points are marked, such as 4000, 3500, 3000, 2500, 2000, 1500, 1000, 500, and 0 (sea level).
- Other Features:** **POISON HILL**, **PORCUPINE RIDGE**, **TRANQUILLE PLATEAU**, **RED PLATEAU**, **RED DOUBT HILLS**, **Denali River**, **Klondike River**, **Klondike Creek**, **Bog Lake**, **Denali Lake**, **Tranquille Lake**, **Redoubt Lake**, **Denali Pt.** (at the bottom left).

P L A T E A U

BONAPARTE LAKE
(Est. - 1888)

KUK-WALLS

KOATL POINT

POISON HIDE

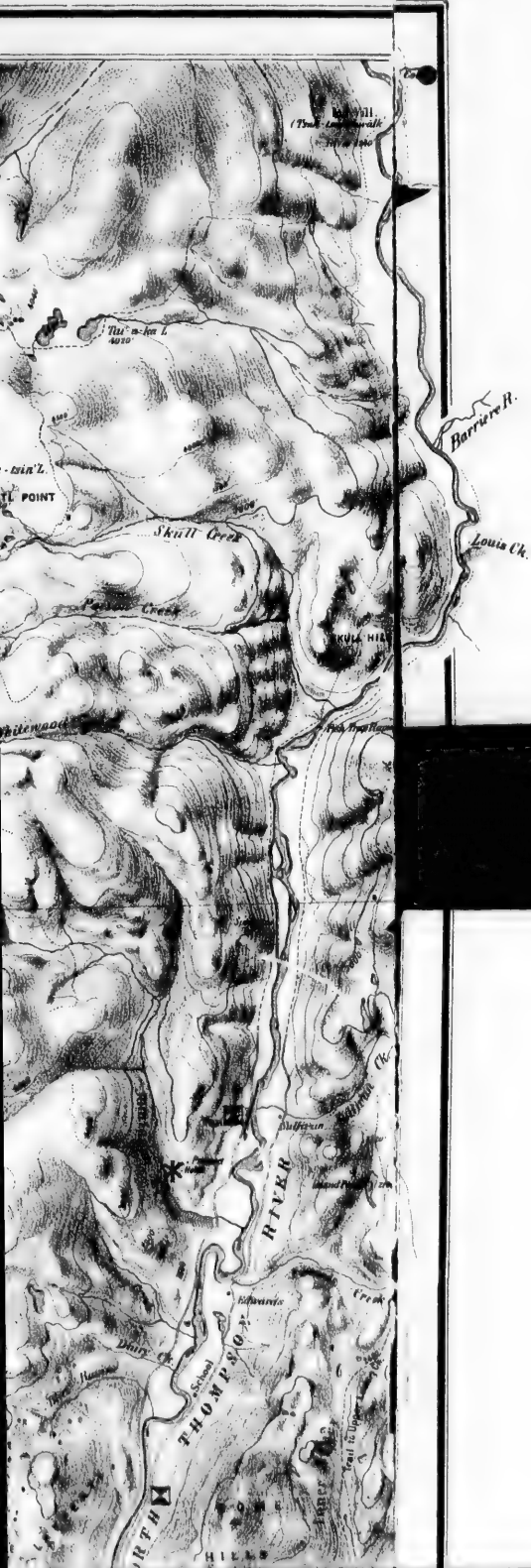
PORCUPINE RIDGE

TRANQUILLI

A close-up of a map showing the Red Plateau and Grand Plateau regions. The text "RED PLATEAU" is visible in the upper left, and "GRAND PLATEAU" is visible in the upper right. The map features contour lines and a small inset map in the bottom left corner.

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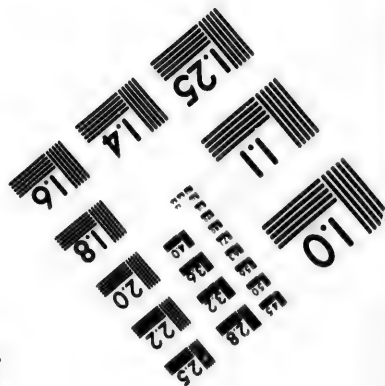
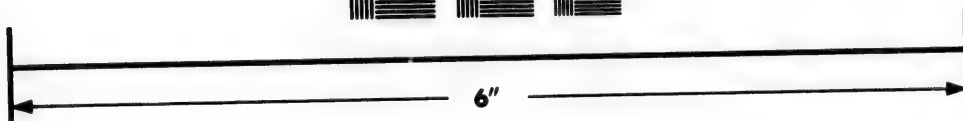
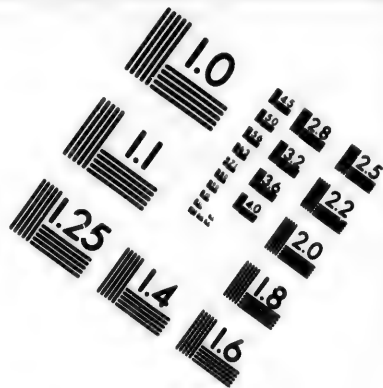




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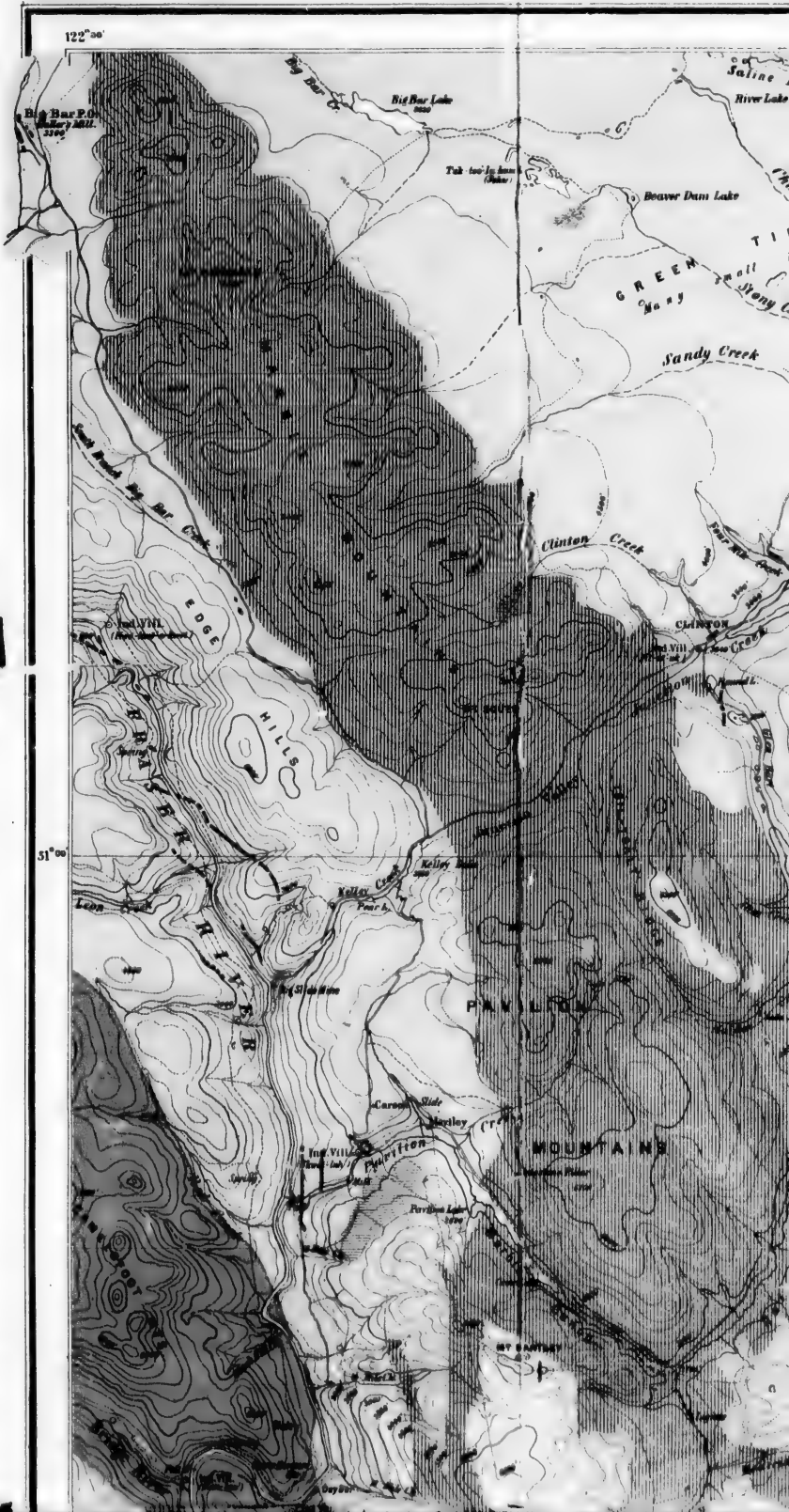
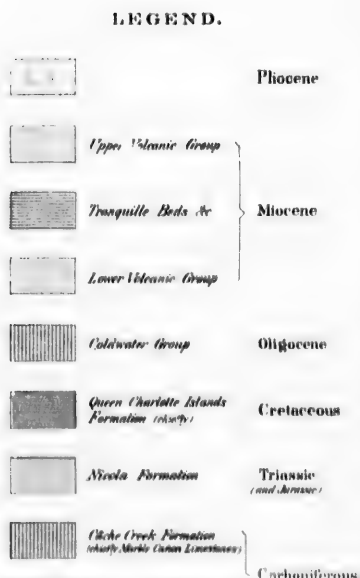
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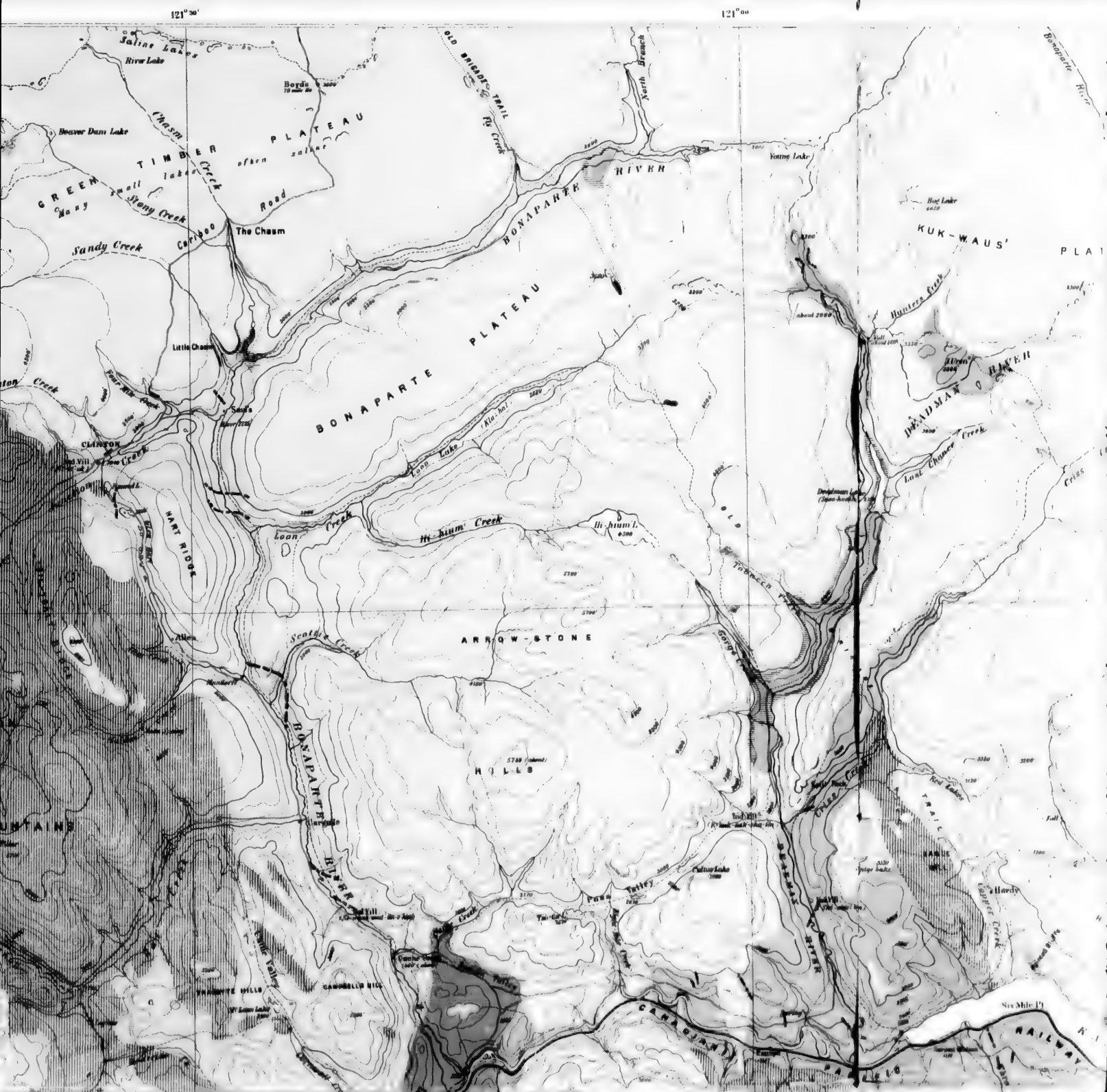
Sheet



Geological Survey of Canada.

GEORGE M. DAWSON, C.M.G., LL.D., F.R.S. &c. DIRECTOR.

1893.



EXPLANATORY NOTES.

The greater part of the region included by the map is more or less thickly covered by superficial or "drift" deposits, due to the Glacial period, although the Coast Ranges, the Marble Mountains, and some less considerable areas, are rather notably free from such deposits. The superficial deposits are generally thick and almost continuous on the various plateaus, boulder-clay being the most important. In the valleys and lower tracts such deposits are less regular, although wide-spread terraces or "benches" composed mostly of gravels, sands and silts are found. These generally consist of re-arranged materials of the boulder-clay. Details are given in the accompanying report, where the relations of these drifts to the occurrence of alluvial gold are also explained. The superficial deposits are not indicated on the map which relates entirely to the "solid geology."

PLIOGENE.

A single small patch of conglomerate in the Fraser Valley is assigned with doubt to this period. On the possible occurrence of additional Pliocene see Report.

MIOCENE.

The rocks of this period are almost entirely of volcanic origin. Those of the Upper Volcanic group are preponderantly basalts and basalt-breccias, with smaller quantities of melaphyre, mica-trachyte, mica-andesite and various porphyrites. No attempt is made to separate these upon the map, but some local details are contained in the Report. The basalts and basalt-breccias, often in nearly horizontal flows or beds, cover extensive tracts, of which the most uniform is the Green Timber Plateau. These Upper Volcanic rocks appear to have been applied from numerous local vents of which Skoatl Point, Porcupine Ridge, the vicinity of Kamloops Lake and probably the Arrowstone Hills, are believed to afford examples. Chalcedony, agates and various zeolites are abundant in some parts of these rocks, and hyalite occurs.

The Tranquille beds, although almost entirely composed of fine grained tuffs and other volcanic materials, have been laid down in water and are often well bedded. They pass in some places into tuffaceous agglomerates and are generally pale in colour. Fossil plants are found in a few places, and near Kamloops, thin beds of good coal. The Tranquille beds proper and some other similar beds, both newer and older, are indicated on the map by the same colour. Where very thin layers of stratified material outcrop, they are indicated on the map by blue dots.

The Lower Volcanic group consists mainly of augite-porphyrates, of grey, greenish and purplish colours. Some of these have been lava flows, while others are fragmental, either agglomerates or tuffs. Mica-porphyrates, plerite-porphyrates and numerous other species are also more sparingly represented. The chief region of eruption at this time is marked by the Clear Mountain Range and its southward continuing high lands, along which a line of active volcanoes undoubtedly existed in the early Miocene. Previous to this great period of volcanism, and perhaps also during stages in its progress, some water-bedded deposits of a local character were formed.

Cinnabar, copper ores and small quantities of native copper are found in association with the rocks of the Lower Volcanic group near Copper Creek.

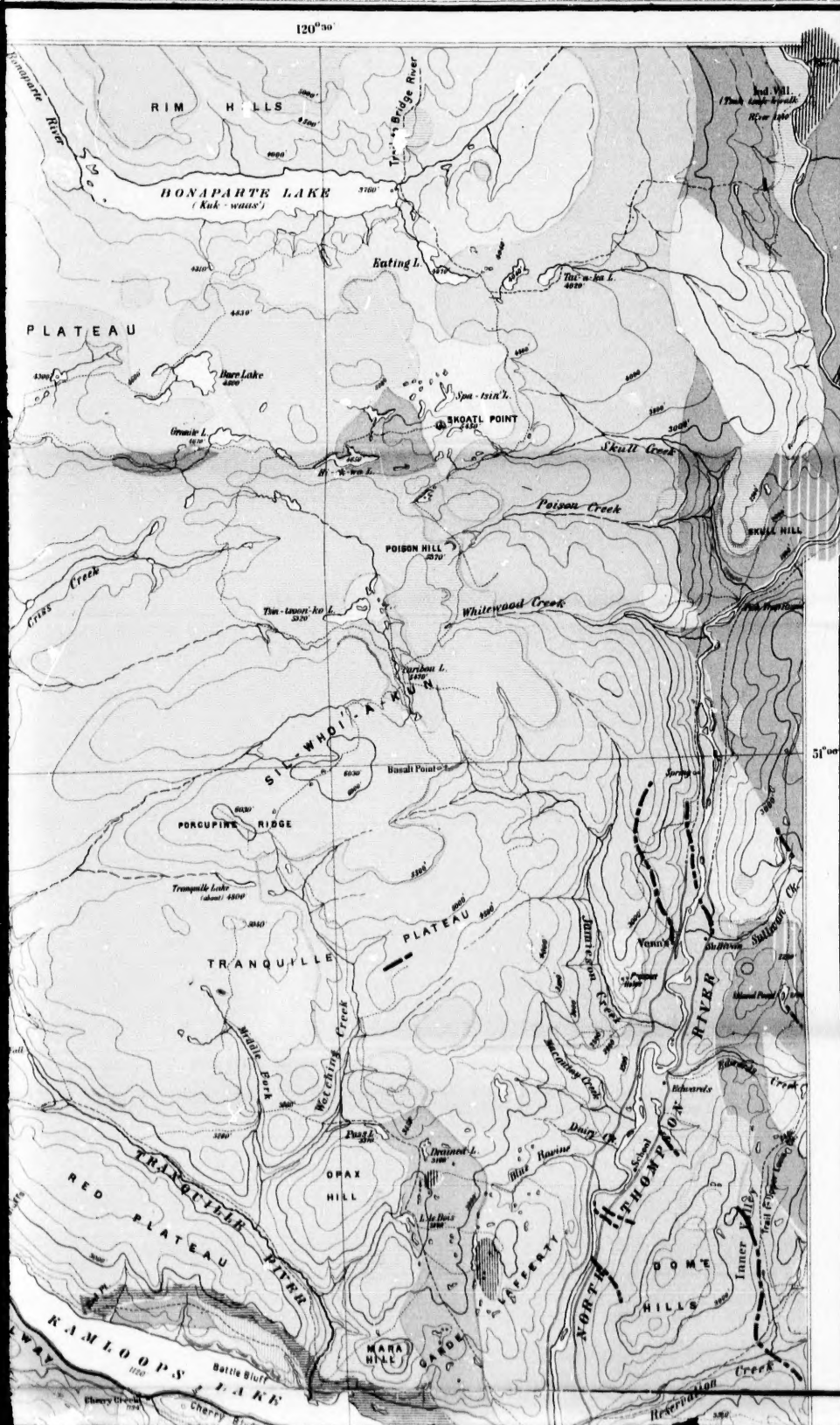
COLDWATER GROUP.

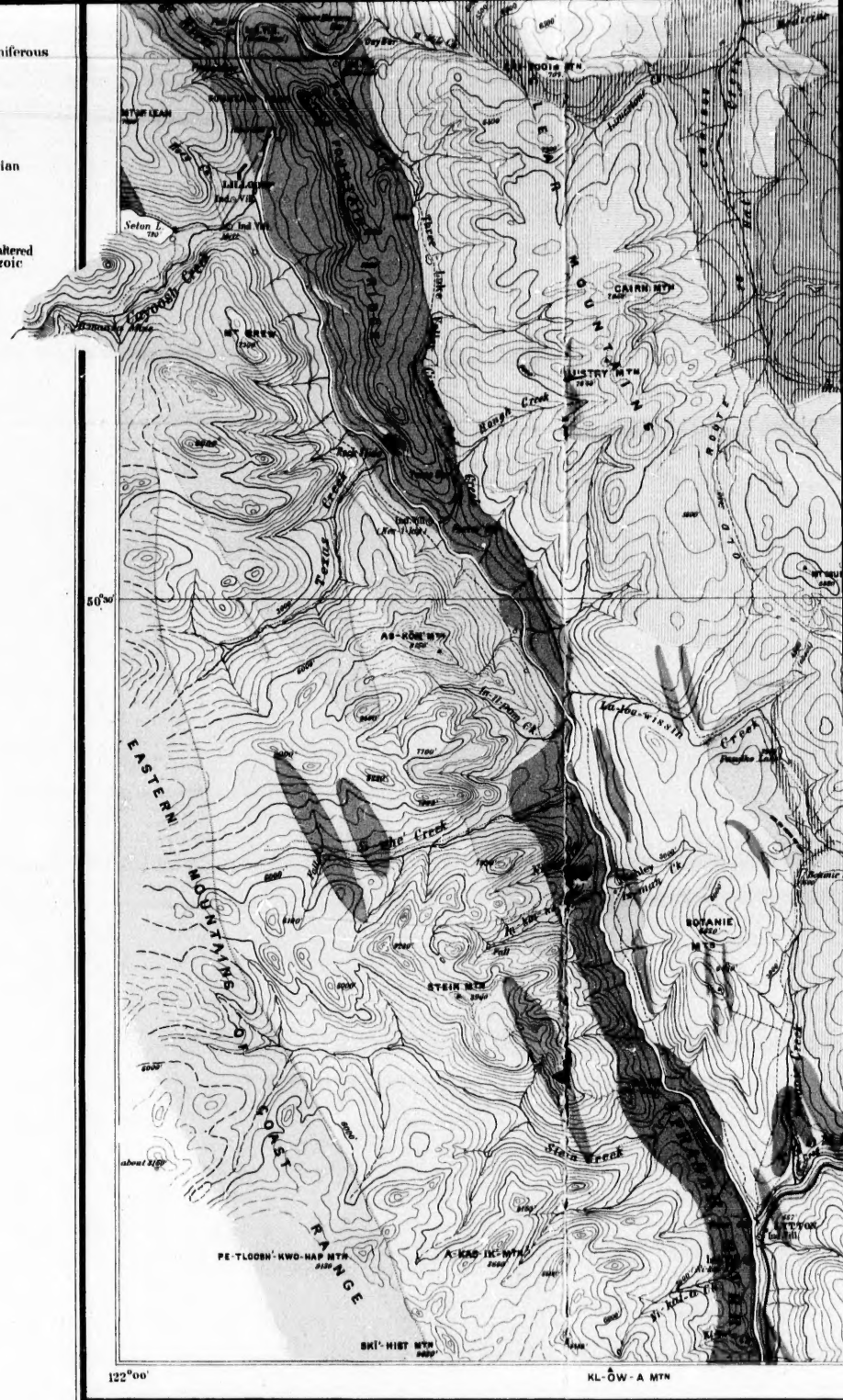
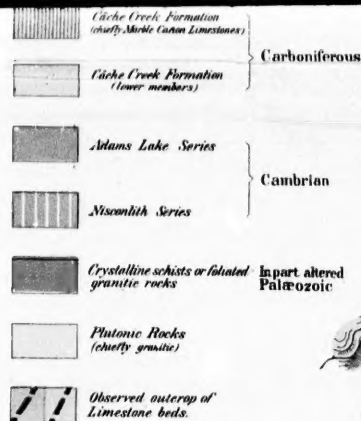
These rocks antedate the period of volcanic eruptions and consist entirely of ordinary water-formed deposits, conglomerates, sandstones and shales, in some places holding coal and lignite. They appear to have been locally upturned and denuded before the Miocene period, and are attributed, although with some doubt, to the Oligocene. None of the beds are marine. The characteristic conglomerates are chiefly composed of quartzite pebbles derived from rocks of the Cache Creek formation, and are often very thick. They are largely represented near the lower part of Hat Creek and near Copper Creek. Lignite-coal occurs on the upper part of Hat Creek, on Guichen Creek near the edge of the map, and coal on the North Thompson, near the north-east corner of the map. In these places the beds are chiefly shales and sandstones. Important deposits of coal and lignite-coal occur on the Nicola four miles beyond the south edge of the map, and the associated rocks here include conglomerates. It is not quite certain that all these now isolated occurrences represent the same geological horizon.

Traces of gold have been found in a few of the conglomerates, and it is possible that some of them may prove to contain workable quantities of gold.

QUEEN CHARLOTTE ISLANDS FORMATION.

These rocks belong to the earlier part of the Cretaceous period. They consist chiefly of hard sandstones and conglomerates, often greenish, and hard dark argillites. The beds are much disturbed and gently nearly on edge. They contain a few fossils. Some beds newer than those of the Queen Charlotte Islands formation are probably in





Compiled and drawn by James McEvoy B.A.Sc.

-  Roads.
-  Pack-trails.
-  Exploratory routes.
-  Indian Villages.
-  Sites of old Indian Villages.
(Kee-wah houses)

Nat. Scale $\frac{1}{253,440}$

Statute Miles

Geographical Miles

Contours 500 feet vertical interval



- A MTH 121°30' 121°00' Longitude West from Greenwich

Nat Scale 1:250,000

Statute Miles

Geographical Miles

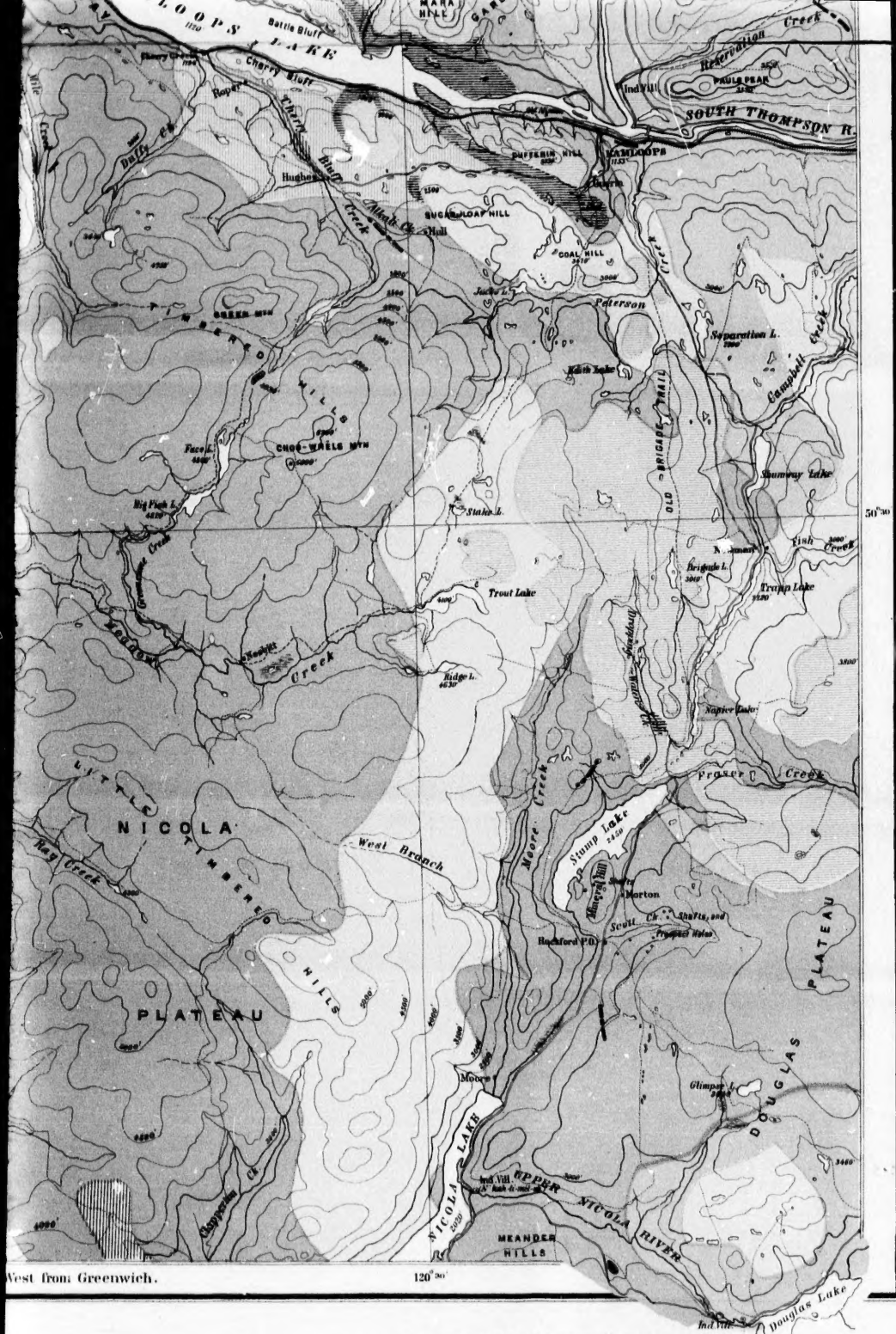
Contours 500 feet vertical interval.

British Columbia
KAMLOOPS SHEET
GEOLOGICALLY COLOURED.

by George M. Dawson C.M.G., L.L.D., F.R.S.

1895

THE CANADA ENG. & LITH. CO. LTD. MONTREAL



West from Greenwich.

GEOGRAPHICAL AND TOPOGRAPHICAL DATA.

Instrumentally surveyed lines as follows:—Line of Canadian Pacific Railway, as measured for Base by Dominion Lands Surveys. Trial location lines of C. P. Ry. Surveys from Lillooet via Marble Canon and up Bonaparte Valley, also along north side of Kamloops Lake and up N. Thompson Valley. Lines by Dominion Lands Surveys within the Railway Belt, chiefly near Kamloops, Savona and Ashcroft. British Columbia Government Land Surveys about Nicola and Stump Lakes.

Some paced surveys (1877) and numerous observations for latitude by G. M. Dawson, have also been employed. Apart from the above sources of information, the geographical outlines, with the whole of the topography, depend upon triangulation, track-surveys and sketches by J. McEvoy.

Cretaceous period. They consist chiefly of hard sandstones and conglomerates, often greenish, and hard dark argillites. The beds are much disturbed and are frequently nearly on edge. They contain a few marine fossils. Some beds newer than those of the Queen Charlotte Islands formation are probably included under this colour.

NICOLA FORMATION.

These rocks are referred, as a whole, to the Triassic period, although it is by no means certain that their lower limit corresponds exactly with the base of that formation. The colour on the map includes also some limited areas believed to be Lower Jurassic (marked J, in red), but the rocks of which cannot be definitely separated from those known by their contained fossils to be Triassic. The rocks are for the most part of volcanic origin, and the tract occupied by them on the map may be described in general terms as a great area of "greenstone." There are, however, some intercalated beds of marine limestones and argillites. The volcanic rocks are in general distinctly separable from those of the Miocene because of the amount of alteration they have undergone. Diabase-porphyrates are abundant, and these are occasionally still amygdaloidal. Agglomerates composed of similar materials are common, and pass into diabase-tuffs which are often finely water-bedded and are sometimes altered into felsite- or petrosilex-like rocks. The colours are generally greenish, grey or occasionally purplish.

Some of the limestones of this formation are suitable for making lime. The ores of the vicinity of Stump Lake, containing gold, silver and copper, also occur in this formation.

CACHE CREEK FORMATION.

Fossils of Carboniferous age are sparingly found in the rocks of this formation, but some of its lower members may possibly be of considerably greater age. The upper part of the formation consists exclusively of limestone, which often becomes marble. It is separately denoted on the map as the Marble Canon limestones. The lower part contains thin beds of limestone, but is preponderantly composed of dark argillites, cherty quartzites and contemporaneous volcanic products. The latter comprise both effusive rocks, agglomerates and tuffs, with some beds of nearly pure serpentine. The volcanic rocks most usual are extremely decomposed diabase-porphyrates and these, together with the argillites, frequently become schistose.

An important belt of such schistose rocks, largely argillites, follows the lower part of the Fraser Valley, and veins in these rocks have evidently contributed largely to the supply of placer gold along this part of the river.

In the vicinity of Stump Lake and Campbell Creek, the rocks coloured as Cache Creek are dark slaty amphibolites and argillites. They are referred to this formation with some doubt.

On both sides of the North Thompson, the Cache Creek rocks are chiefly represented by argillites, gneisses, and diabases with some limestone.

The rocks of this formation are almost invariably shattered and dislocated in an extreme degree. Quartz veins are abundant in many places and have been proved to be auriferous on Cayoosh Creek and at the Big Slide mine, Kelly Creek.

ROCKS CLASSED AS CAMBERIAN.

No direct evidence of the age of these rocks is obtained on this sheet, but they have been traced eastward to Adams Lake and Shuswap Lake where their relations are better known. The upper or Adams Lake series is chiefly composed of green chloritic or felspathic schists, derived by dynamic metamorphism from ancient volcanic rocks. These, near the North Thompson, are found in some places still massive, as much decomposed diabase. The underlying Nicola series is characterized by dark argillite schists or phyllites, passing into micaceous schists.

CRYSTALLINE SCHISTS, ETC.

Some rocks of this class, which occur in association with the granites, in the vicinity of the Fraser River, are indicated by a separate colour. They are probably in part highly altered Palaeozoic rocks, in part foliated granitic materials, and include micaceous and hornblende schists, and gneissic materials.

PLUTONIC ROCKS.

These are coloured pink upon the map, and though in all cases intrusive in their relations to the other rocks, vary considerably in character. The larger areas are, however, almost exclusively occupied by gray granitic rocks of different types, but between which no distinct lines can generally be drawn. Syenite occurs in some places, and on Kamloops Lake and westward along the Thompson valley, considerable areas of gabbro, closely associated with the granites, are included under the same colour. The chief granitic intrusions have occurred about the close of the Triassic period, but some later granites are found cutting through Cretaceous rocks.

Quartz veins holding gold occur in a granitic mass at Jameson Creek, and distinct traces of gold are found in the mass of syenite on Edward's Creek, east of the North Thompson.